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FATIGUE SENSOR EVALUATION PROGRAM LABORATORY TEST REPORT.(U)

OCT 75 R W WALKER, J Y KAUFMAN F33657-71-C-0163

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FATIGUE SENSOR EVALUATION PROGRAM LABORATORY TEST REPORT

DEPUTY FOR SYSTEMS
SPECIALIZED AIRCRAFT PROGRAM OFFICE

CESSNA AIRCRAFT COMPANY
WALLACE DIVISION
WICHITA, KANSAS 67201

OCTOBER 1975

TECHNICAL REPORT ASD-TR-75-33
FINAL REPORT FOR PERIOD JANUARY 1973 - FEBRUARY 1975

AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

Statement A per Mr. Richard Culpepper, ASD

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A laboratory test was conducted to establish basic performance data for the Micro-Measurements FM Fatigue Sensors. Tests were conducted with emphasis on repeatability, reliability, temperature compensation, and effect of mean strain.

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FOREWORD

This fatigue sensor evaluation laboratory test program was conducted by the Cessna Aircraft Company of Wichita, Kansas under Air Force Contract No. F33657-71-C-0163. The contract was initiated under project A-37B (335A) "A-37B Final Fatigue Program", and Task No. P00003. This report has been prepared as a part of Task P00026.

The work was supervised and directed by Robert W. Walker, Group Leader. This report was adapted from Cessna Report 318E-7319-047," Fatigue Sensor Evaluation Program - Laboratory Test Report, " by John Y. Kaufman, Design Engineer, and it was prepared for publication by Sue Bardsley, Technical Aid. This project was initiated by Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, and was administered under the co-ordination of Richard C. Culpepper (ASD/SD27MS) Aircraft Structural Integrity Program Manager, A-37B.

Based on the encouraging results of the initial Cessna fatigue sensor program, Cessna Report 318E-7219-029, "Program for Evaluation of Annealed Foil Fatigue Sensors", this program was initiated to provide a broad data base upon which to evaluate the response of the Micro Measurements' FM series Fatigue Sensor. An extensive test program was conducted in order to establish reliable response rates for cyclic loading and temperature variation. The data analysis was conducted on a "no data scatter " basis. That is, for each piece of data which varied from the "norm", a positive or at least a probable cause was established for that deviation. Subsequent use has confirmed the validity of the response rates established.

This report covers work conducted from January, 1973 until October, 1974. It was submitted by the author in April, 1975. The contractors report number is 318E-7319-047.

Publication of this report does not constitute Air Force approval of the reports' findings or conclusions. It is published only for the exchange and stimulation of ideas.

James R. Stanley

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SUMMARY

The Fatigue Sensor Evaluation Laboratory Test Report was prepared per requirements of the A-37B Fatigue Sensor Evaluation Program and under the authorization of Contract F33657-71-C-0163.

A series of thirty-three laboratory component tests were conducted to develop basic performance data for the Micro-Measurements FM fatigue sensor. Six types of tests were performed to define FM sensor response to strain cycles and ambient temperature variations. Both strain cycles and ambient temperatures were patterned after operational aircraft usage (A-37B).

FM multiplier performance was evaluated in terms of effective strain amplification and strain compensation. Four sizes of multipliers were tested (2.0, 2.5, 3.0, 3.5); multiplier sizes are typical of those used for aircraft structure.

Test data have indicated the fatigue sensor to have repeatable and predictable response to strain cycles. The FM fatigue sensor has demonstrated acceptable reliability, accuracy and longevity in this test series. Laboratory component tests have provided necessary baseline data for development of fatigue sensor application to aircraft structural fleet monitoring.

Conclusions:

1. Fatigue sensor response to a wide variety of aircraft loads/environment is known and can be predicted.

2. Test findings indicate the FM multiplier is capable of consistent and reliable strain cycle amplification.

3. The strain gage element of the FM fatigue sensor not only makes the sensor self compensating with respect to residual applied loads but also gives effective temperature compensation.

4. The current FM fatigue sensor/multiplier has two basic limitations:

    a) Limited operational temperature range (-20^{o} to $+130^{o}F$).

    b) Failure rate is high (15%).

SUMMARY (CONTINUED)

Recommendations:

1. Develop the required methodology for quantitative data treatment of fatigue sensor response using basic performance data derived from foregoing and current fatigue sensor programs.

   a) Investigate a direct relation of sensor response to fatigue damage using stress-endurance (S-N) data relationship.

   b) Investigate an indirect relation of sensor response to fatigue damage using Reference 7 exceedance curve method.

2. Extend FM fatigue sensor operation over a broad temperature range compatible with aircraft operations.

SECTION I

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

The strain gage is a wire or foil grid which is bonded to the structure under investigation. It responds to strain in the structure by a reversible change in electrical resistance of the grid. The fatigue sensor is similar in appearance but uses an annealed constantan grid. In additon to the above reaction, the fatigue sensor reacts to strain cycles by an irreversible resistance change due to work hardening of the grid. The FM fatigue sensor[a], (see Figure 1), investigated by this program, incorporates a strain amplifier[b] and a strain gage which is wired into the measuring bridge so as to cancel reversible resistance change due to variations in strain and temperature.

Thus the cumulative ΔR^c of the sensor is an indication of the strain history of the parent structure and may be used as a fatigue monitoring device. This program established a data base and investigated performance characteristics of the FM fatigue sensor as an aid to this purpose.

The laboratory test effort was based on collection of data from six types of tests and thirty-three specimens designed to provide basic performance data for the Micro-Measurements FM fatigue sensor. Response of the FM fatigue sensor to constant amplitude strain cycles, mean strain variation, spectrum loads and ambient temperature variation was developed by analyzing test data. The performance of the FM multiplier was evaluated in terms of reliability, repeatability and stability for aircraft loads and environment.

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[a] FM Fatigue Sensor - Denotes Micro-Measurements fatigue life gage (trade name) installed on FM strain amplifier (see Reference 2).

[b] FM Sensor Multiplier - Trade name for mechanical strain amplifier manufactured by Micro-Measurements as an integral part of the FM fatigue sensor.

[c] ΔR - Resistance change in ohms.

The evaluation of basic fatigue sensor performance parameters was conducted in terms of aircraft structural fatigue monitoring applications. Aircraft operational structure loads and environment similar to the A-37B type aircraft formed the basis of test parameters for these laboratory test series.

The purpose of this report is to present the findings and results of the A-37B Fatigue Sensor Evaluation Laboratory Test Program. This work was conducted per requirements of Reference 1 and under the authorization of Contract F33657-71-C-0163, Contract Change Number P0003.

This report is organized into ten sections and six appendixes. Section I contains the introduction and background and Section II describes six types of tests conducted. Sections III thru VI develop fatigue sensor response to strain cycles, mean strain, spectrum loads and temperature on an individual basis using test data. Section VII discusses performance of the FM multiplier while Section VIII presents a test evaluation of the compressive cycle eliminator. Sections IX and X present the program summary and results, and conclusions and recommendations respectively. Appendix A documents the prediction method for fatigue sensor response and Appendix B presents fatigue sensor installation procedures. Calibration of the readout indicator for fatigue sensor data collection is documented by Appendix C. Appendix D presents an example of the least squares curve fit of raw strain cycle test data. Appendix E presents adjusted ΔR mean strain data at 15 cyclic levels in table form. Appendix F presents a sample of raw test data collected and basic calculated parameters for the laboratory test series (data for specimen #6).

All test methods and operations are presented by this report. Test data analysis methods are discussed. Fatigue sensor response to test parameters are discussed on an individual basis.

Reference 1. - "Fatigue Sensor Evaluation Program", Work Statement, Cessna Report 318E-6918-213, Addendum H, Revision J, 2 June 1972.

1.2 BACKGROUND

The A-37 Aircraft Structural Integrity Program (ASIP) has served as a vehicle to evaluate commercially available fatigue sensors for application to aircraft structural fleet monitoring. An initial program (reference 3) was conducted during 1971-1972 using A-37B laboratory tests and sixteen operational aircraft to evaluate fatigue sensor performance; the following resulted from that program:

a) A potential fatigue sensor application to aircraft structural monitoring is indicated.

b) The Micro-Measurements FM sensor has the best performance for this application compared to other types tested.

c) A comprehensive laboratory test program is needed to develop basic FM fatigue sensor performance data for aircraft type loading and environment.

d) Additional fatigue sensor field data is necessary to evaluate reliability and longevity.

These recommendations were contracted by the on-going Reference 1 program of which the subject laboratory test program is a part.

A review of program data has continued to show the potential of fatigue sensor application to aircraft monitoring. Results of the Reference 1 program are designed to verify this potential with an emphasis on application to monitoring A-37 type aircraft. Program technical effort and concept evaluation has been under the direction of ASD and AFFDL of Wright-Patterson Air Force Base, Ohio.

Reference 3. - "Program for Evaluation of Annealed Foil Fatigue Sensors", Final Report, Cessna Report 318E-7219-029, 30 June 1972.

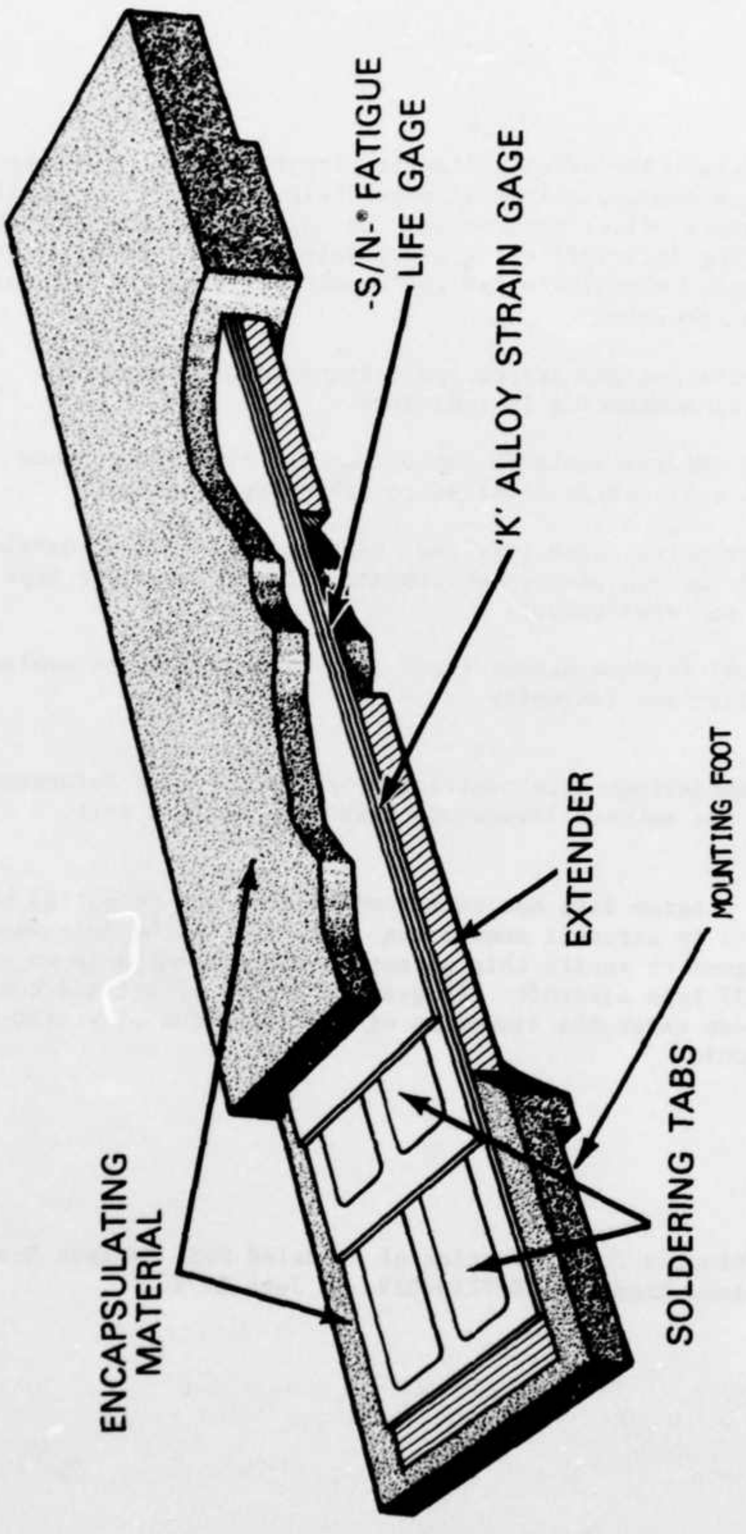

Figure 1 FM Series Multiplier

SECTION II

TEST DESCRIPTION

2.1 CONSTANT AMPLITUDE TESTS

2.1.1 Introduction

Twenty-four specimens with six Micro-Measurements FM fatigue sensors each were cycled under constant amplitude loads (see Table 1). Each specimen was identical in configuration, but cycled with a different constant amplitude load level (23 alternating and mean strain combinations were used, one test was rerun/duplicated). Fatigue sensor, strain gage, and temperature data were collected at selected intervals to produce required sensor response data.

2.1.2 Test Specimens

Each constant amplitude specimen was fabricated from an extruded "I" beam section of 2024-T3511 aluminum (19 inches long). This section, except for material, was a standard CM3504-1 extrusion (Cessna Standard for Extrusion Die No. AND 10140-1402) with a cross sectional area of 0.594 square inches (see Figure 2). A pair of tapered load distribution blocks were bonded and bolted to each end of the specimen using Hysol EA-9309 adhesive and sixteen NAS 464-3-25 bolts. The specimen load blocks were match drilled to attach end fixtures to mate with the MTS[a] loading machine (Figure 11). The test specimen was designed to provide an area of constant strain distribution for fatigue sensor instrumentation and to have ample strength for maximum test loads.

2.1.3 Instrumentation

Each specimen was instrumented with three Micro-Measurements FM fatigue sensors centered on the outer face of each flange. Each fatigue sensor was flanked by a pair of Micro-Measurements CEA[b] series strain gages (CEA-13-125UW-120) to determine the specimen strain at each fatigue sensor location. In addition, two Micro-Measurements TG[c] temperature sensors (ETG-50DP) were mounted on the "front" face of the specimen. The location and identification of all instrumentation are shown in Figures 3 and 4 and in photographs, Figures 5 and 6.

---

[a]MTS - A trade name for Materials Testing System Model No. 483.01.

[b]Micro-Measurements CEA - General purpose strain gage with constantan grid, polyimide backing and direct leadwire attachment.

[c]Micro-Measurements TG - Bondable resistance thermometer gage fabricated from high purity nickel foil.

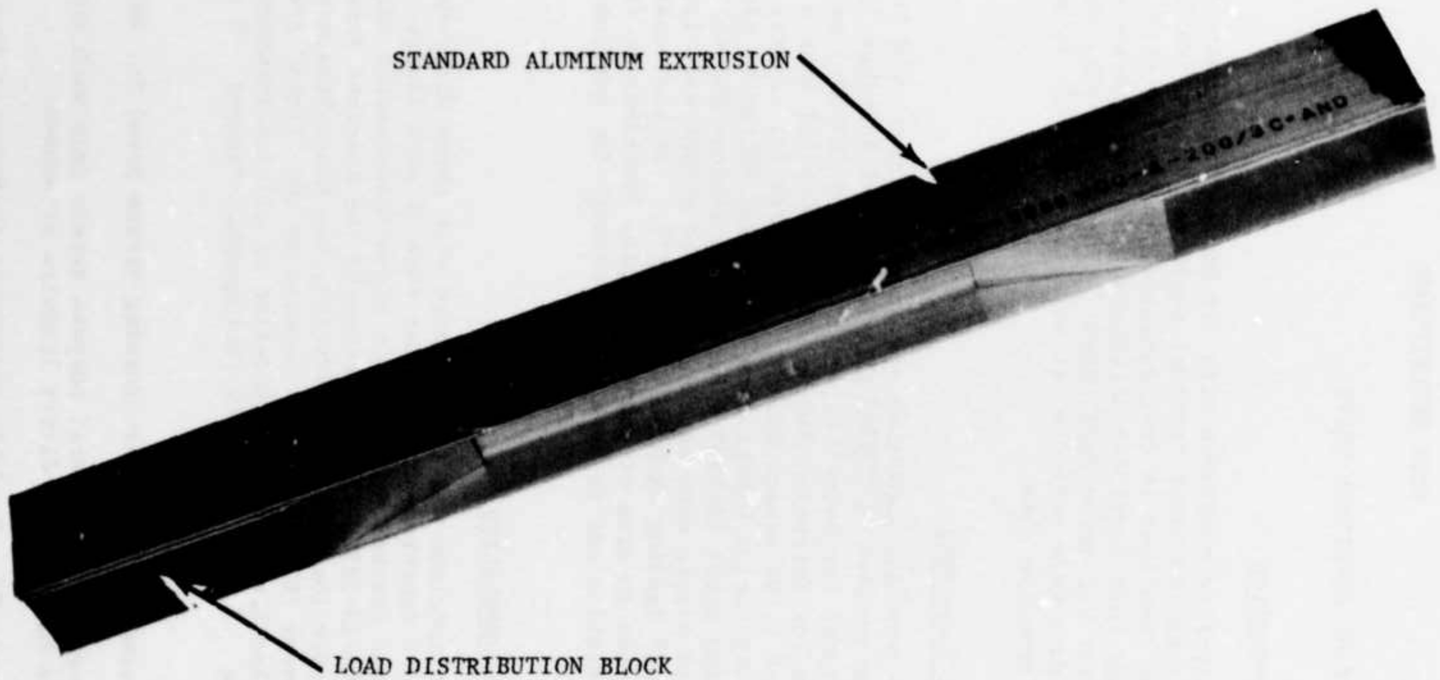

Figure 2 Basic Test Specimen

TABLE 1 LABORATORY TEST SUMMARY

Test No.	Test Type	Description[1]	Ref. Section
1	Constant Amplitude	±500 Alt, 0 Mean	2.1
2		±750 Alt, 0 Mean	2.1
3		±1000 Alt, 0 Mean	2.1
4		±1250 Alt, 0 Mean	2.1
5		±1500 Alt, 0 Mean	2.1
6		±500 Alt, +1000 Mean	2.1
7		±750 Alt, +1000 Mean	2.1
8		±1000 Alt, +1000 Mean	2.1
9		±1250 Alt, +1000 Mean	2.1
10		±1500 Alt, +1000 Mean	2.1
11		±500 Alt, -1000 Mean	2.1
12		±750 Alt, -1000 Mean	2.1
13		±1000 Alt, -1000 Mean	2.1
14		±500 Alt, -500 Mean	2.1
15		±750 Alt, -500 Mean	2.1
16		±1000 Alt, -500 Mean	2.1
17		±1250 Alt, -500 Mean	2.1
18		±1500 Alt, -500 Mean	2.1
19		±500 Alt, +500 Mean	2.1
20		±750 Alt, +500 Mean	2.1
21		±1000 Alt, +500 Mean	2.1
22		±1250 Alt, +500 Mean	2.1
23	Constant Amplitude	±1500 Alt, +500 Mean	2.1
24	Spectrum Load	Random Order #1	2.4
25	Spectrum Load	Random Order #2	2.4
26	Ambient Temp Cycle	7 Cycles, -67°F to 125°F	2.3
27	Cyclic Temp	±1000 Alt, Ambient Temp	2.2
28	Cyclic Temp	±1000 Alt, +150°F Temp	2.2
29	Cyclic Temp	±1000 Alt, -60°F Temp	2.2
30	Cyclic Temp	±1000 Alt, 0°F Temp	2.2
31	Temp Induced Cycle	+150 to -50°F, Alum Specimen	2.5
32	Temp Induced Cycle	±150 to -50°F, Steel Specimen	2.5
33	Constant Amplitude	Rerun of Test #1	2.1

[1]Load levels indicated are in units of microstrain

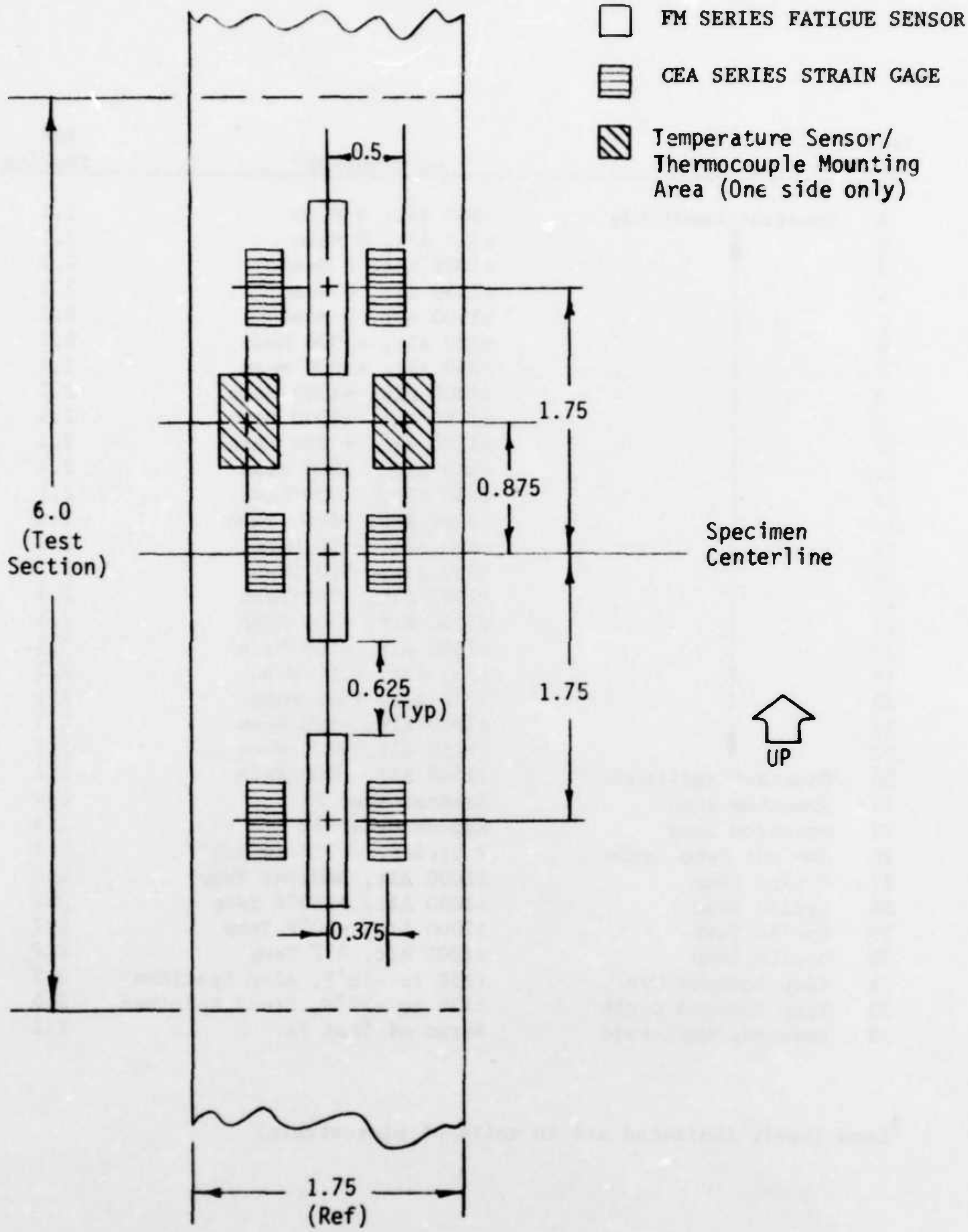

Figure 3 Instrumentation Configuration

FATIGUE SENSOR		TEMPERATURE SENSOR	IDENTIFICATION NUMBERS
SENSOR NUMBER	SENSOR TYPE	Micro-Measurement TG temperature sensors will be used for all specimens with the exception of specimen numbers 24 and 25 which will replace one TG sensor with a thermo-couple.	○ Strain Gage △ Fatigue Sensor □ TEMPERATURE SENSOR
1U	FM221-02.5L		
2M	FM221-02.5L		
3L	FM221-02.5L		
4U	FM211-02.0L		
5M	FM221-03.0L		
6L	FM311-03.5L		
7L, 8L	FDA-02	Installed only on specimen number 26	

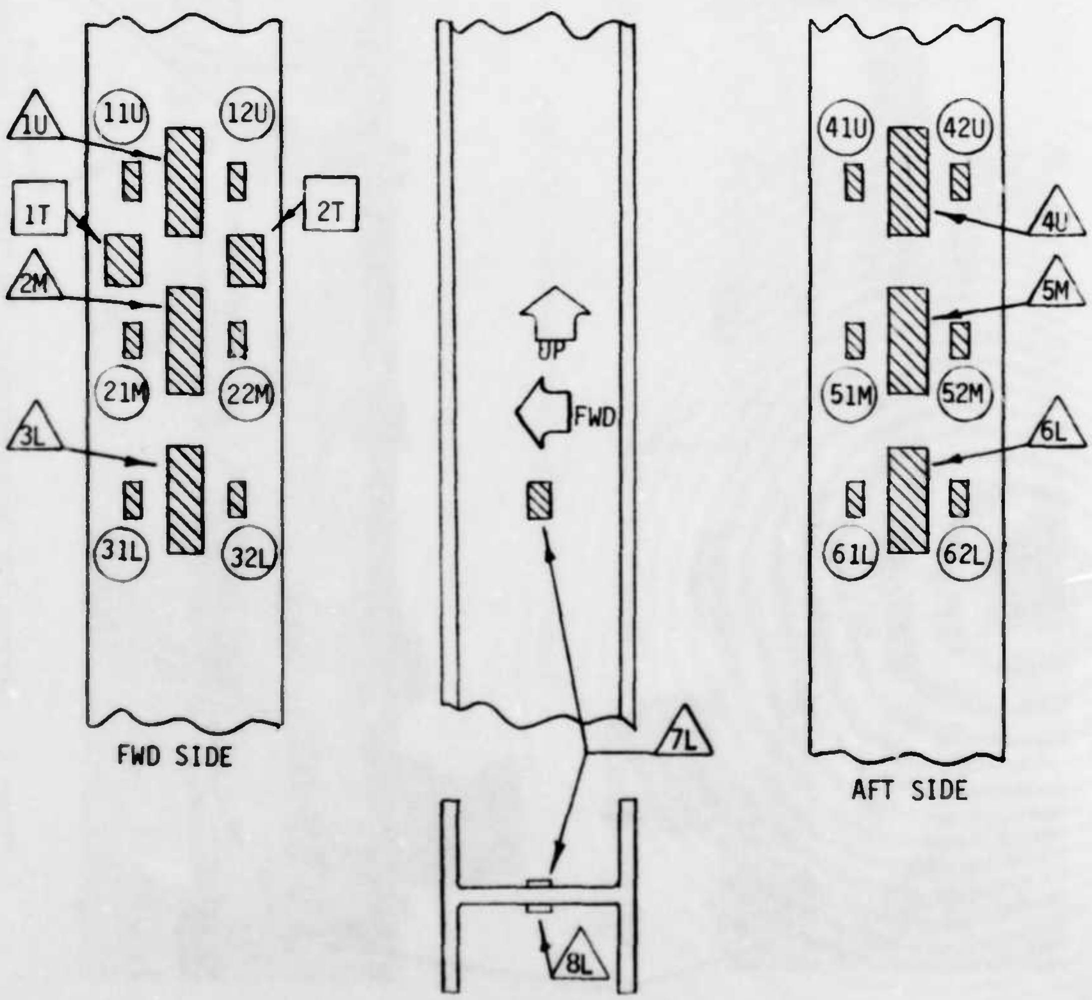

Figure 4 Instrumentation Identification

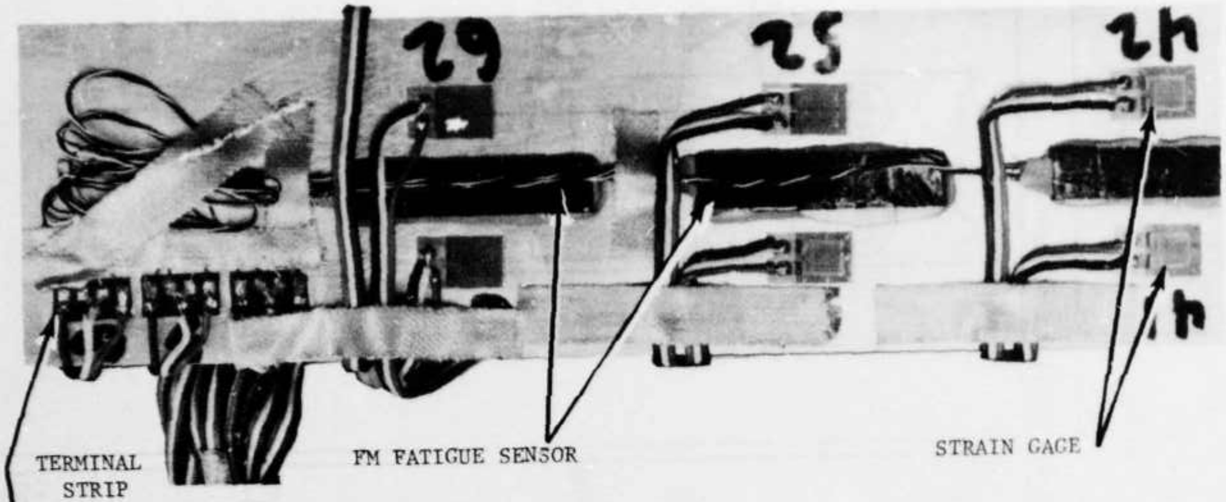

Figure 5 Specimen Instrumentation, Aft Side

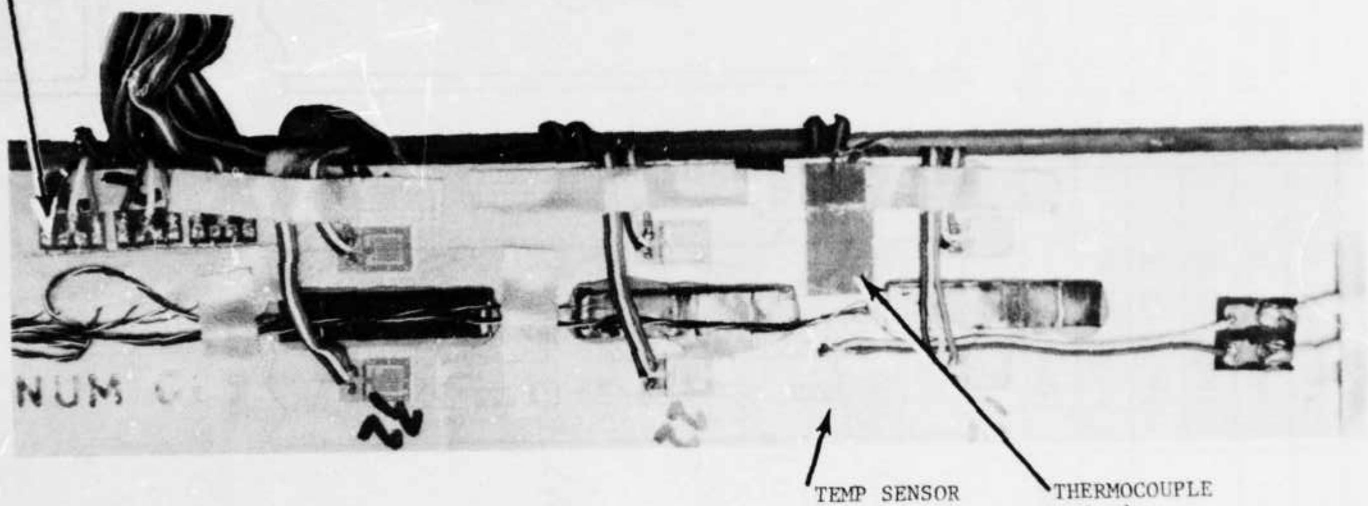

Figure 6 Specimen #26 Instrumentation, Fwd Side (Other Specimens Similar)

The fatigue sensors were mounted on the specimen with Micro-Measurements M-16[d] adhesive using the procedure outlined by Appendix B and the strain gages and temperature sensors were mounted with Eastman 910 adhesive. Figure 7 shows a completed specimen in the oven used to heat cure the M-16 adhesive (two hours at 140°F). The leads from all gages were connected to solder tab terminal strips (Figure 5), which were attached to the interconnecting cables leading to the data collection switch box.

2.1.4 Data Collection System

The interconnecting cables from the test specimen were attached to the data collection panel shown in Figures 8 thru 10. The signal from the panel was read out on two Vishay Model P-350[e] strain indicators. The data collection panel was a Cessna built item which contained a switch position for each fatigue sensor, strain gage, and temperature sensor. It also contained a zero reference (Micro-Measurement S-100-05 precision 100 ohm resistor) for the initial zero adjustment of each strain indicator. In addition, another switch selected the composite sensor (half bridge readout), the fatigue sensor element, or the strain gage element of the six FM fatigue sensors, as well as switching in the required dummy resistor used in reading the individual sensor elements (quarter bridge readout).

The two Vishay strain indicators were fitted with lead wires and plugs to permit plugging them into the appropriate receptacles on the face of the panel. For the resistance readings taken in ohms, the gage factor setting on the Vishay P-350 was adjusted to 9.82 to produce a direct reading of the deviation from the zero reference with 0.001 ohm resolution. See Appendix C for indicator calibration. For all readings taken in microstrain[f], the gage factor was adjusted to manufacturer's specifications for each gage (approximately 2.00).

The data collection panel was designed to minimize the data collection effort and data errors by minimizing gage factor changes and switching operations. Also, the panel protected the zero reference and switch components of the data collection system.

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[d] Micro-Measurements M-16 - Special flexibilized two component epoxy adhesive formulated specifically for bonding the FM series multiplier.

[e] Vishay Model P-350 - Indicator employing resistance bridge circuit used to read resistance change of fatigue sensors for all laboratory tests.

[f] Microstrain (or $\mu\epsilon$) - Strain with units of inches per inch X 10^6.

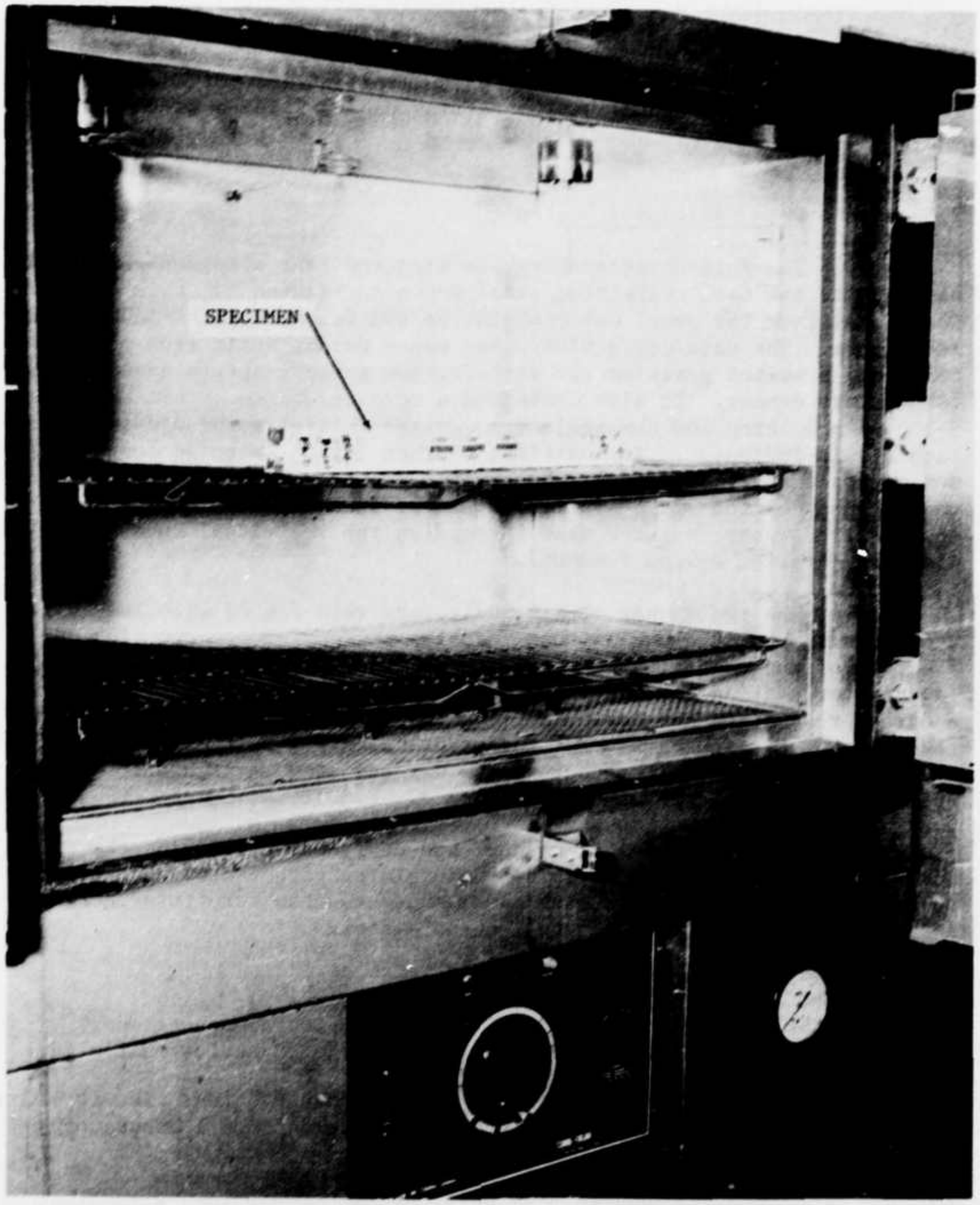


Figure 7 Instrumentation Adhesive Cure in Oven

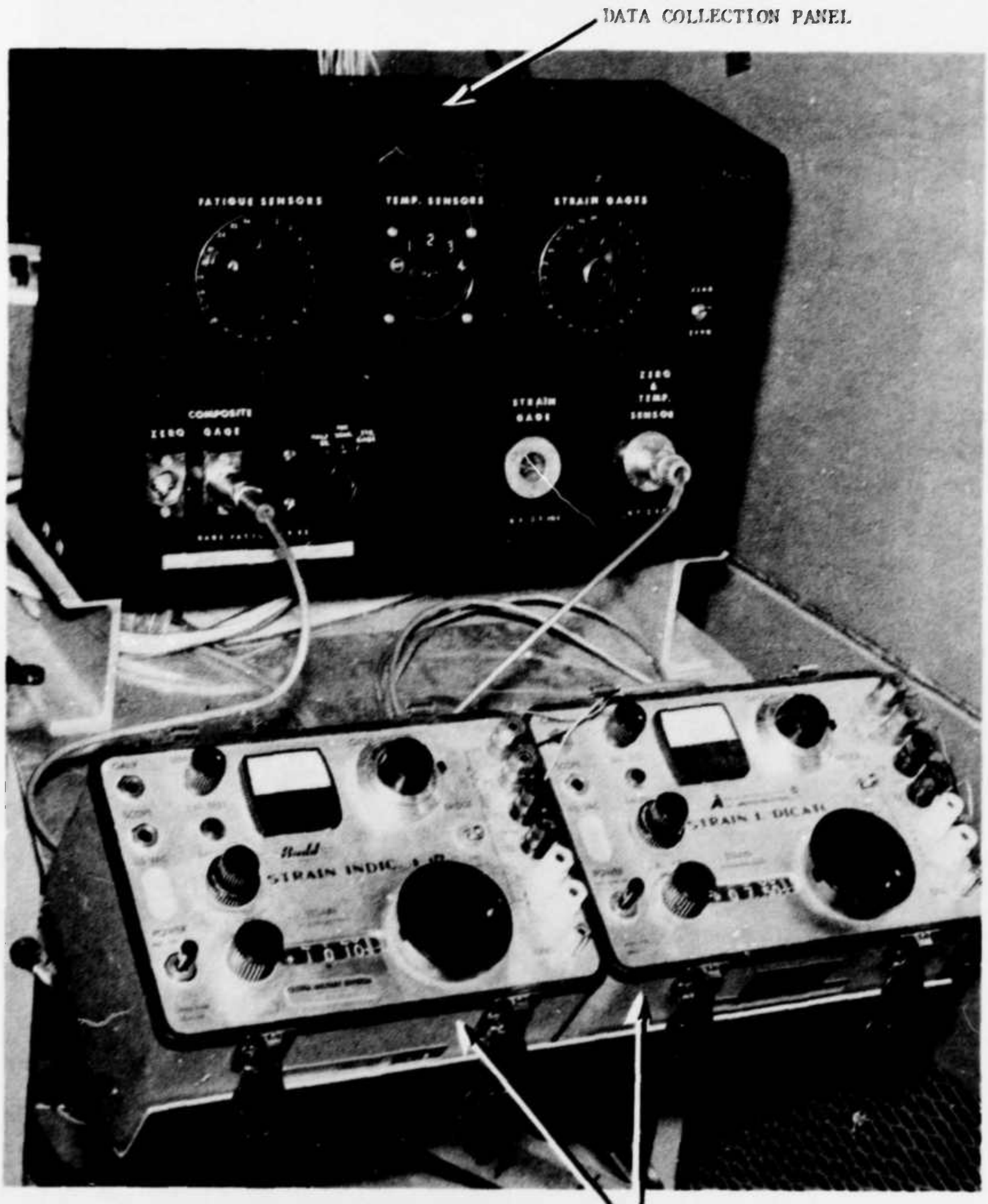


Figure 8 Data Collection Panel

Figure 9 Data Collection

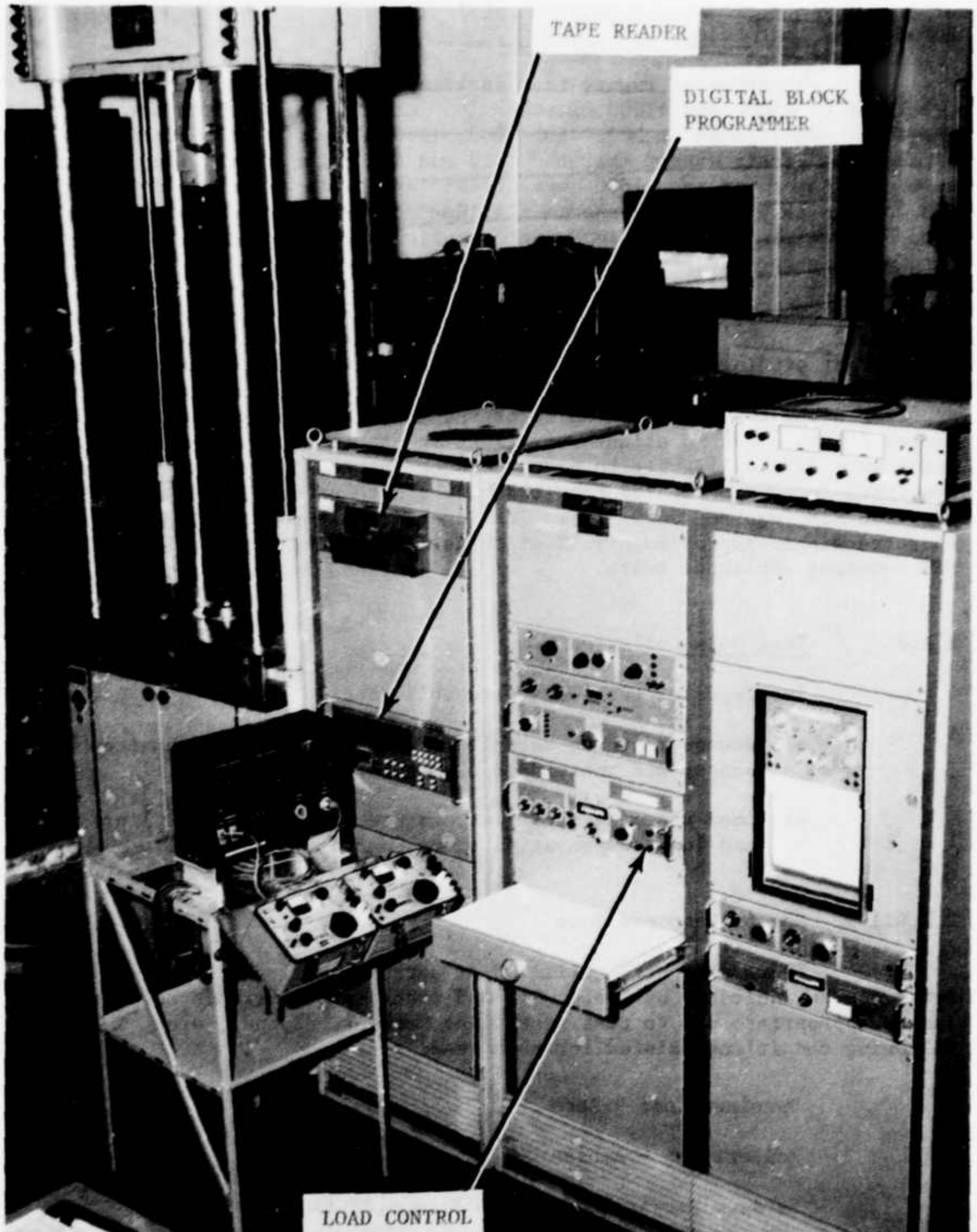


Figure 10   MTS Machine And Data Readout Components

2.1.5 Test Loads

A series of twenty-four specimens was cycled at mean strain levels of 0, ±500, and ±1000 microstrain. At each mean strain level a specimen was cycled at 500, 750, 1000, 1250, and 1500 microstrain alternating strain except that the 1250 and 1500 microstrain load levels were eliminated for the -1000 mean strain level. In addition, specimen #33 was run as a repeat of specimen #1 due to defective fatigue sensors used on specimen #1. Test loads were applied by a MTS cyclic test machine (Figure 10).

The loads applied to each of the test specimens are outlined in Table 2 . The applied load (lbs) in each case was adjusted to give target strain values (με) for the particular specimen being tested. This adjustment was made during the initial static load cycle for each specimen using the average reading of specimen strain gages to set target strain. Due to slight variations in specimens, the applied loads were varied slightly to give the same target strain on individual specimens (e.g. specimen #3 required 6360 lbs to produce 1000 με while specimen #18 required 6400 lbs). Test specimen alternating strain operated within approximately 3% of target along the test section for all constant amplitude tests.

2.1.6 Test Data Collected

Two types of test data were collected:

a) Sensor response data (resistance change of composite sensor and individual elements).

b) Load response data (performance of strain multipliers and load compensation under load).

2.1.6.1 Sensor Response Data

These data were collected at approximate logrithmic intervals as indicated by Table 5 , and other such intervals as were judged appropriate due to test scheduling, sensor response, etc. The following conditions existed for each reading:

Specimen Load - Zero

Temperature - Ambient

Fatigue Sensor Indicator G.F. - 9.82 (Readout = ohms)

Temperature Indicator G.F. - 2.00 (Readout = degrees F)

TABLE 2 CONSTANT AMPLITUDE TEST LOADS

Spec. No.	Alt. Strain (με)	Mean Strain (με)	Max. Load (lbs)	Min. Load (lbs)	Cycles Applied	Comments
1	±500	0	+3190	-3190	1,000,000	2 defective sensors
2	±750	0	+4790	-4790	560,000	
3	±1000	0	+6360	-6360	300,000	
4	±1250	0	+7960	-7960	40,000	
5	±1500	0	+9470	-9470	30,000	
6	±500	+1000	+9470	+3190	1,000,000	
7	±750	+1000	+11050	+1570	1,000,000	
8	±1000	+1000	+12720	0	1,000,000	
9	±1250	+1000	+14324	-1600	200,000	
10	±1500	+1000	+15860	-3190	75,000	Poor sensor bond
11	±500	-1000	-3190	-9635	1,000,000	
12	±750	-1000	-1620	-11340	750,000	
13	±1000	-1000	0	-12980	250,000	
14	±500	-500	0	-6440	1,000,000	
15	±750	-500	+1600	-8000	1,000,000	
16	±1000	-500	+3170	-9600	400,000	
17	±1250	-500	+4860	-11360	200,000	
18	±1500	-500	+6400	-13050	50,000	
19	±500	+500	+6290	0	500,000	Specimen overloaded, failed
20	±750	+500	+7940	-1600	1,000,000	
21	±1000	+500	+9470	-3200	400,000	
22	±1250	+500	+11034	-4850	80,000	
23	±1500	+500	+12768	-6442	65,000	
33	±500	0	+3127	-3179	1,000,000	Rerun of specimen #1

The following data were collected at each reading:

1. Composit sensor resistance (ohms)
   (half bridge with compensating strain aage)

2. Resistance of fatigue sensor element (ohms).

3. Resistance of strain gage element (ohms).

4. Specimen temperature

5. Ambient temperature

6. Supporting data such as:

   a) Reading number

   b) Number of applied cycles

   c) Date/time

   d) Test personnel

   e) Any other factors which might affect the test data.

Table 3 is the data form which was used for sensor response data. Appendix F presents a sample of the raw sensor response test data collected for specimen #6 (Table F-1).

TABLE 3 SAMPLE DATA COLLECTION FORM
SENSOR RESPONSE DATA

SENSOR RESPONSE DATA COLLECTION FORM				
SPECIMEN NO.	READ NO.	READING BY	CHECKED BY	COMMENTS
DATE	ACCUM. TEST CYCLES	INDICATOR S/N	G.F. SETTING	
TIME				

ROOM TEMP - THERMOMETER	SPECIMEN TEMP - SENSOR #1	SPECIMEN TEMP - SENSOR #2

SENSOR IDENT.	MULT. SETTING	COMPOSITE SENSOR (OHMS)	STRAIN GAGE ONLY (OHMS)	FATIGUE SENSOR ONLY (OHMS)	COMMENTS
1-U	2.5				
2-M	2.5				
3-L	2.5				
4-U	2.0				
5-M	3.0				
6-L	3.5				

2.1.6.2 Load Response Data

At selected intervals, also approximately logrithmic, data were collected from specimen instrumentation during the application of a static load cycle. This data collection schedule is shown by Table 5. Data were also taken at other such intervals as were judged necessary. Data were taken at the following points in the load cycle:

1. Zero load
2. Maximum load (maximum tension or minimum compression)
3. Mean load
4. Minimum load
5. Zero load

The following conditions existed for each reading:

Specimen load - Five points of load cycle

Temperature - Ambient

Indicator G.F. - 9.82 (readout = ohms)

Indicator G.F. - 2.08 for individual sensor elements (readout = microstrain of amplified strain)

Indicator G.F. - 2.105 for specimen strain gages (readout = microstrain)

Indicator G.F. - 2.00 for TG temperature sensors (readout = degrees F)

The following data were taken at each load point:

1. Composite sensor resistance (half bridge with compensating strain gage - readout = ohms).
2. Strain indicated for fatigue sensor element (readout = microstrain).
3. Strain indicated for the compensating strain gage element (readout = microstrain).
4. Specimen strain at each fatigue sensor location (readout = microstrain).
5. Specimen temperature
6. Ambient temperature

7. Supporting data such as:

   a) Reading number

   b) Number of applied cycles

   c) Applied load

   d) Date/time

   e) Test personnel

   f) Any other pertinent facts.

Table 4 is the form used for the collection of these data. Appendix F presents a sample of the raw load response data collected for specimen #6 (Table F.3).

2.1.7 <u>Data Collection Schedule</u>

Both sensor response and load response data were collected in accordance with the schedule shown in Table 5. In addition, readings were taken at other such intervals as were judged desirable by test personnel.

2.1.8 <u>Test Operation</u>

Prior to the installation of instrumentation on specimen #1, a photoelastic strain survey was conducted to determine the strain distribution across the faces of the test specimen. A photoelastic coating was applied over the gage area on each face, and a series of calibration loads covering the full range of test loads was applied. The photoelastic readings taken insured that the distribution of strain across the gage area was acceptable. Figure 11 shows the setup used for this survey.

For each test specimen of the constant amplitude series, an identical test procedure was used. Following the installation of the end fixtures (see Figure 11), a "bench zero" set of readings was taken on the twelve specimen strain gages. The specimen was then mounted in the MTS test machine (Figure 10). This machine was a Materials Testing System Model No. 483.01. The installation of the specimen in the machine is shown in Figure 12 thru 15. An initial static load cycle was then

TABLE 4 SAMPLE DATA COLLECTION FORM
LOAD RESPONSE DATA

LOAD RESPONSE DATA COLLECTION FORM						
SPECIMEN NO.	ACCUMULATED CYCLES	DATE	READ BY	ROOM TEMP	TEMPERATURE SENSOR #1	TEMPERATURE SENSOR #2
		TIME				

APPLIED LOAD (LBS)	FATIGUE SENSOR DATA				STRAIN GAGE DATA			
	NO.	COMPOSITE (OHMS)	FAT. SENSOR ($\mu\varepsilon$)	STRAIN GAGE ($\mu\varepsilon$)	NO.	INDICATED ($\mu\varepsilon$)	NO.	INDICATED ($\mu\varepsilon$)
0	1U				11U		12U	
	2M				21M		22M	
	3L				31L		31L	
	4U				41U		42U	
	5M				51M		52M	
	6L				61L		62L	
+3190	1U				11U		12U	
	2M				21M		22M	
	3L				31L		32L	
	4U				41U		42U	
	5M				51M		52M	
	6L				61L		62L	

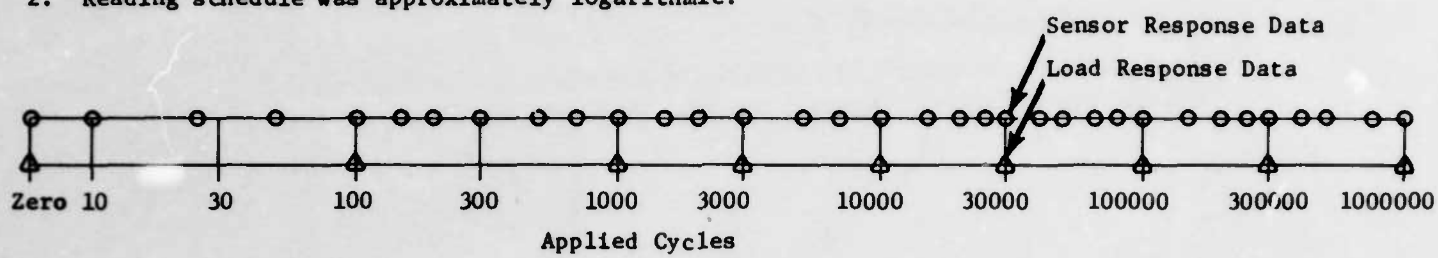
TABLE 5 DATA COLLECTION SCHEDULE

1. Data was collected for each constant amplitude specimen per this schedule until:

   a) All fatigue sensors were open circuit or $\Delta R = 8$ ohms.

   or, b) Applied specimen cycles reached 1,000,000.

2. Reading schedule was approximately logarithmic.



Read No.	Applied Cycles	Type Data: Sensor	Type Data: Load
Zero	0	X	X
1	10	X	
2	25	X	
3	50	X	
4	100	X	X
5	150	X	
6	200	X	
7	300	X	
8	500	X	
9	700	X	
10	1000	X	X
11	1500	X	
12	2000	X	
13	3000	X	X
14	5000	X	
15	7000	X	
16	10000	X	X
17	15000	X	
18	20000	X	
19	25000	X	
20	30000	X	X
21	40000	X	
22	50000	X	
23	65000	X	
24	80000	X	
25	100000	X	X
26	150000	X	
27	200000	X	
28	250000	X	
29	300000	X	X
30	400000	X	
31	500000	X	
32	750000	X	
33	1000000	X	X

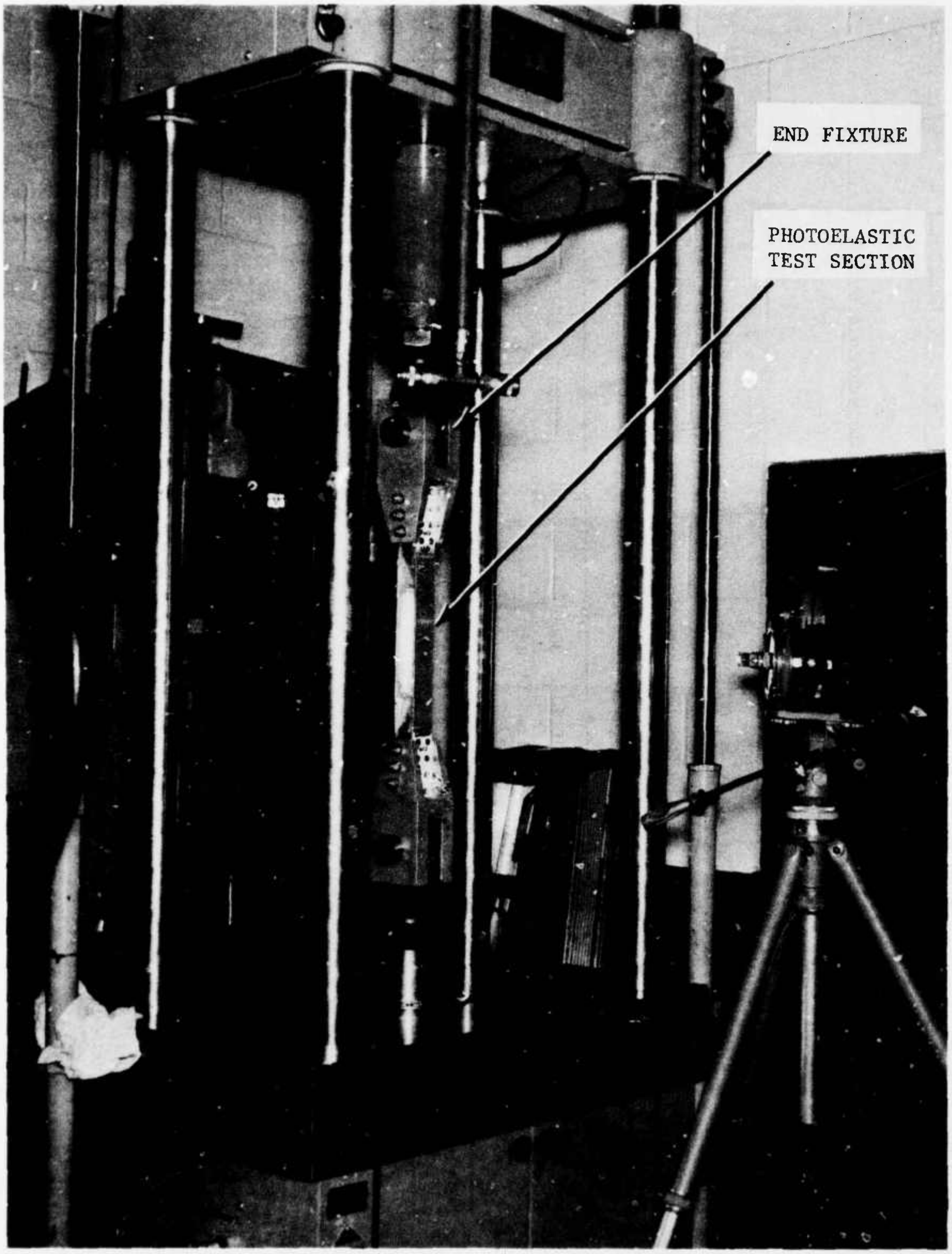


Figure 11 Photoelastic Test Of Specimen #1

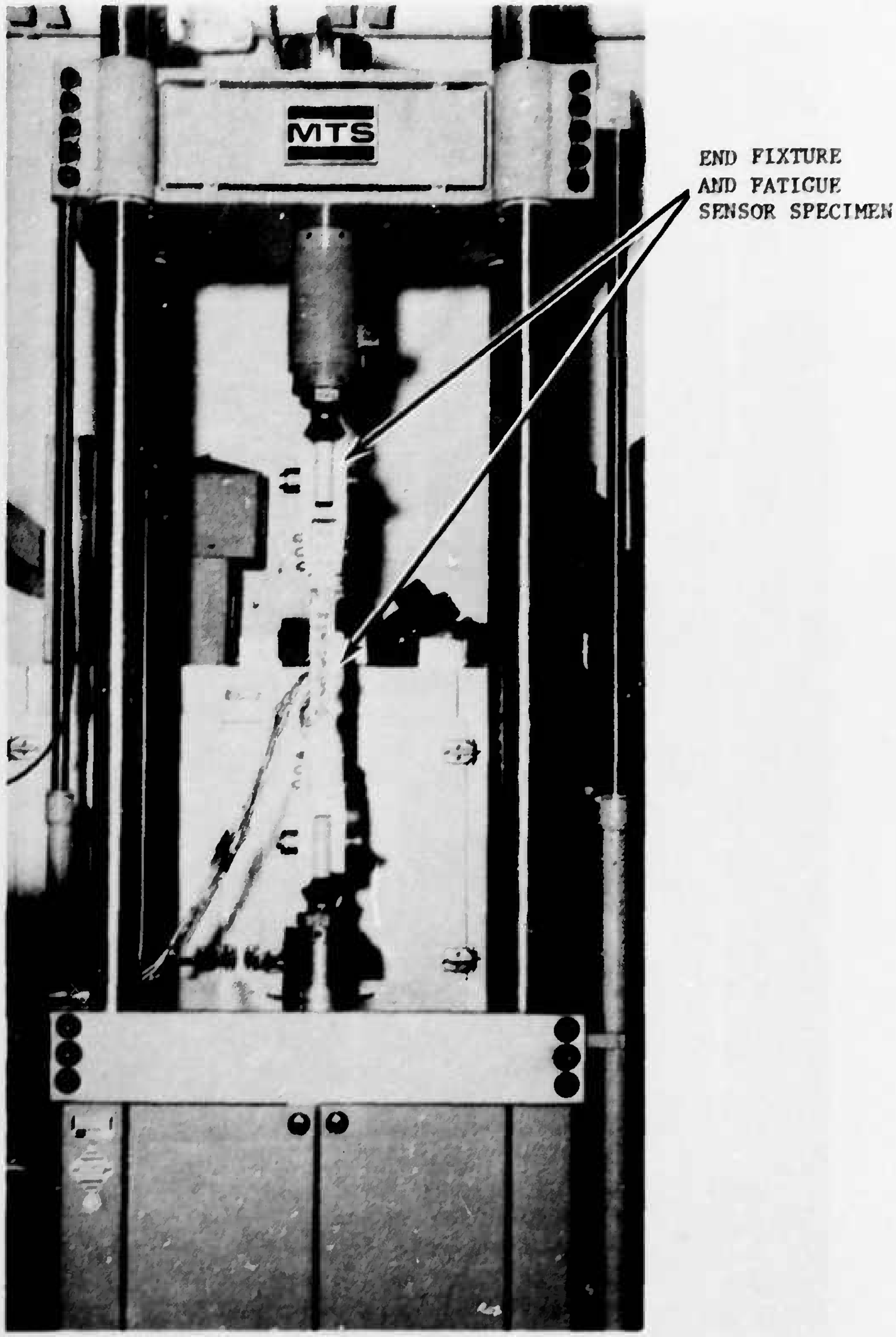


Figure 12 Specimen In MTS Machine

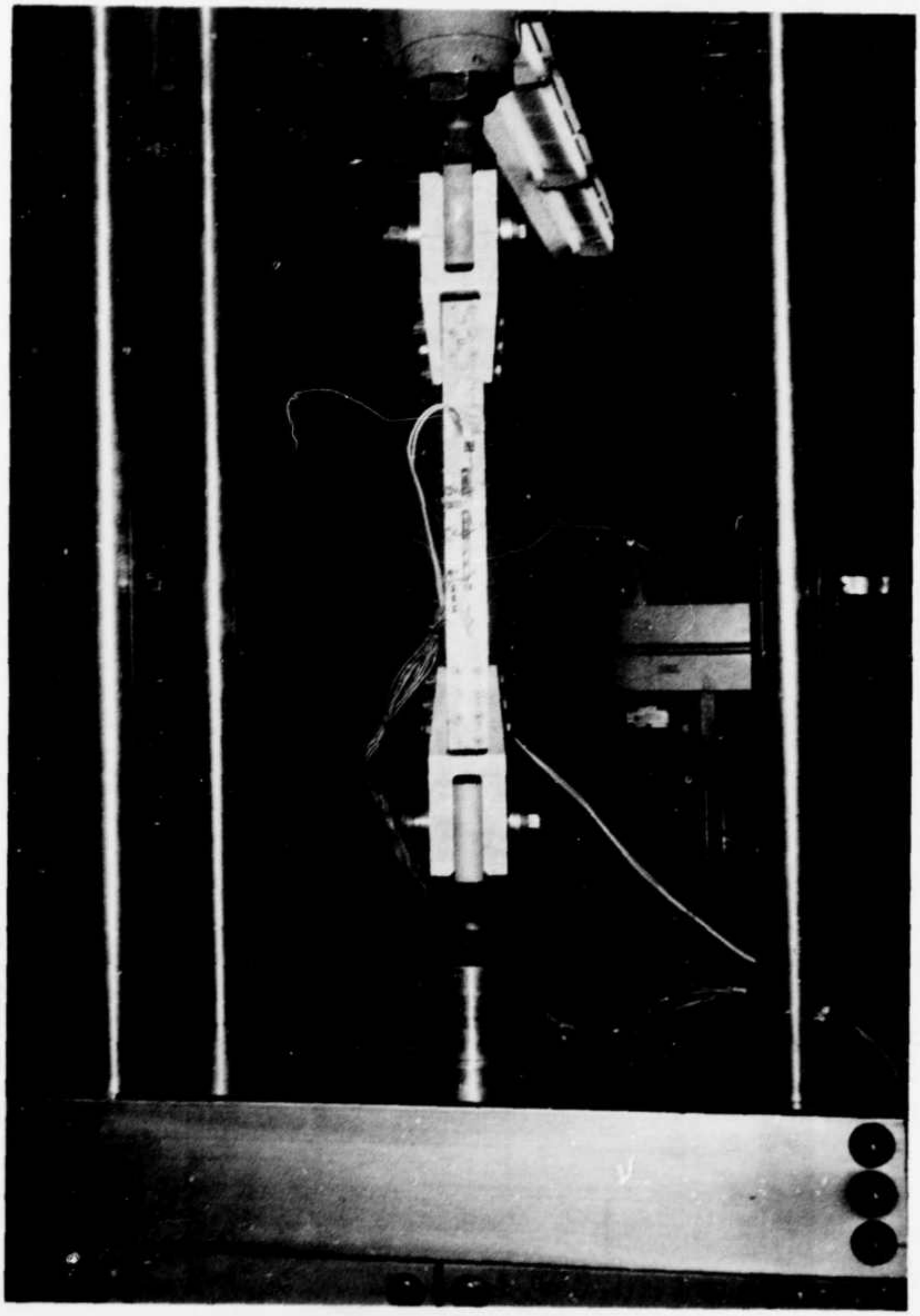


Figure 13 Specimen In MTS Machine

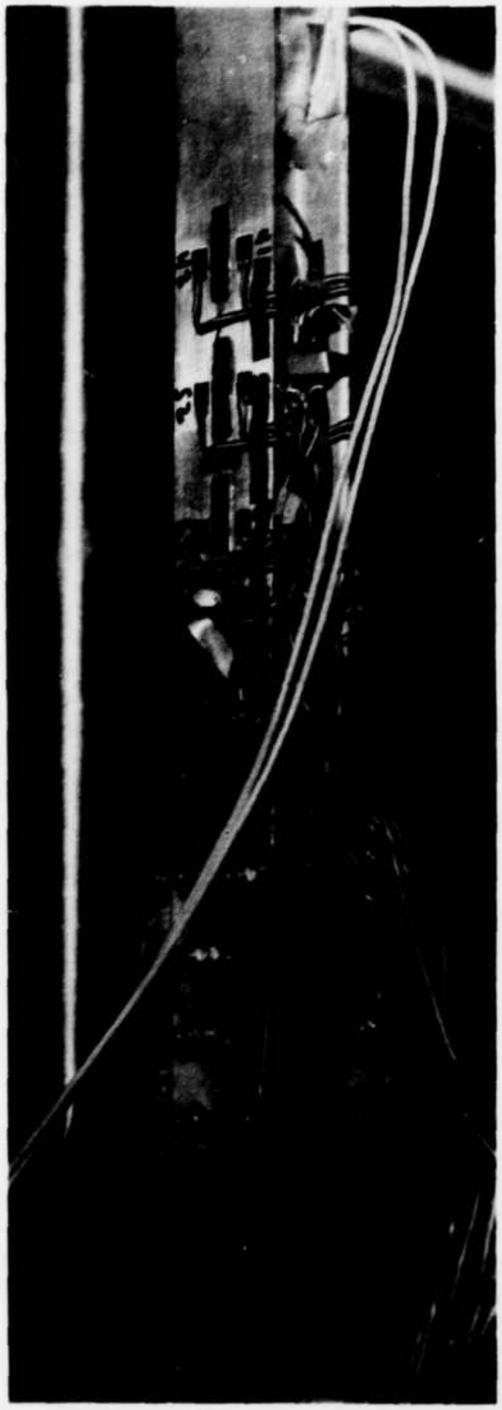


Figure 14 Specimen Mounting

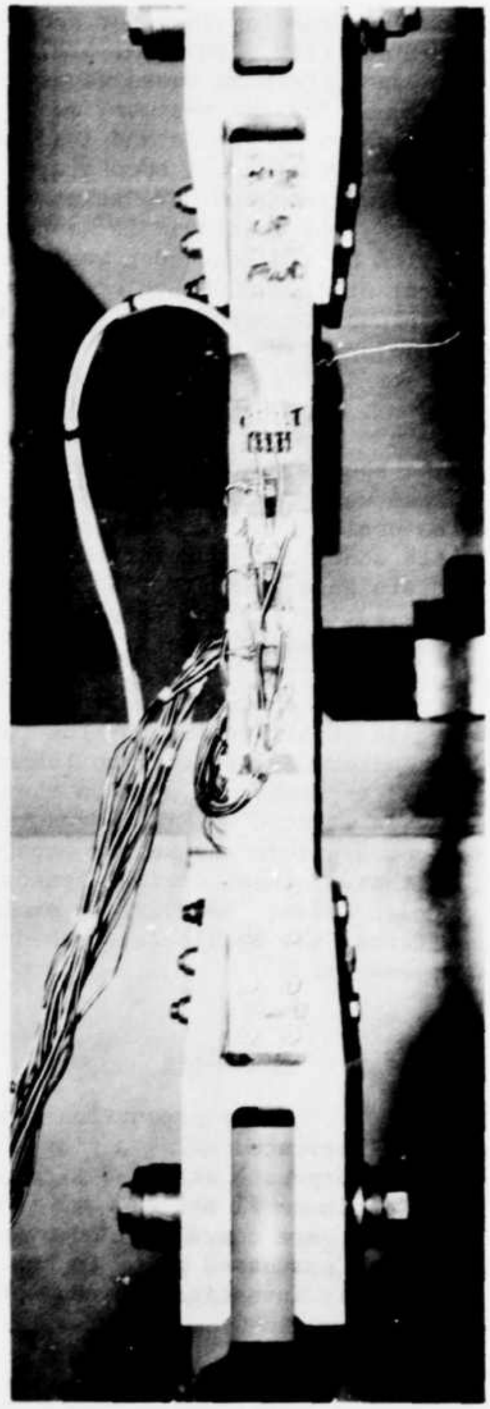


Figure 15 Specimen In MTS Machine Close-Up

applied to establish the actual test loads which would produce the target strains for that particular specimen. This was done by applying a target load and reading the four specimen strain gages at the mid-section of the specimen (21M, 22M, 51M, 52M). The load was then adjusted such that the average strain on these gages was the target strain. This procedure was followed for the maximum, mean, and minimum strain levels. The initial zero sensor response and load response readings were taken during this load cycle. Cycling was then started using the established test loads, and required readings were taken in accordance with the schedule of Table 5. Testing was continued for each specimen until all fatigue sensors had failed or had reached a resistance change (Delta R) of 8 ohms, or a total of 1,000,000 cycles had been applied. Computer programs were developed to permit rapid reduction and examination of test data and a "running plot" of Delta R (ΔR) versus applied cycles was kept for each sensor during the test operation.

As a check of the dynamic load stability of the test machine/test specimen, oscillograph records were taken early in the program. These were taken with the test specimen cycling at 2 cps, 5 cps and 10 cps; the oscillograph was attached to the specimen instrumentation to record both specimen (unamplified) strain gages and fatigue sensor (amplified) strain gage elements. No discrepancy in loading was detected and alternating strains were consistent with those measured during static load cycles.

An investigation was conducted concerning the possibility of cyclic strain heating of the fatigue sensor elements. One fatigue sensor was altered by opening up the encapsulation material and inserting a small thermocouple next to the sensor elements. A second fatigue sensor was fabricated by Micro-Measurements which had a temperature sensor mounted within the sensor encapsulation next to the sensor elements. Neither of these special sensors showed any significant heating due to cyclic loads. However, to exclude the possibility of any detrimental effects, the cyclic rate schedule of Table 6 was followed for specimens #6 and on.

2.1.9 Anomalies

Early production runs of the FM sensors (Lot No. 153 and down) were fabricated using a single layer of encapsulating material and did not incorporate attached wire leads. All sensors with the 2.5 multiplier on specimens #1 and #2 were from Lot No. 137 and were of this type. These sensors were characterized by premature failure. For this reason, all sensors purchased prior to Lot No. 154 were returned to Micro-Measurements for their investigation and specimen #33 was run as a repeat of specimen #1.

TABLE 6 CYCLE APPLICATION RATE SCHEDULE

Cycle Rate Schedule (CPS)				
Alternating Strain	Accumulated Cycles			
	0-1000	1000-10000	10000-100000 ⚠1	100000-1000000 ⚠1
±500	1	5	7	10
±750	1	3	5	7
±1000	1	2	5	5
±1250	1	2	5	5
±1500	1	2	3	5

⚠1 A 20 minute stabilization period was required after cycling was stopped before collecting <u>load cycle data</u>. (This was not required for fatigue sensor data readings.)

The test data from specimen #10 indicated some irregularities in sensor multiplier performance. Examination of the specimen at the completion of testing revealed that a poor bond existed between the specimen and some of the sensors. Additional care was exercised in the installation of instrumentation on the remainder of the specimens, and no further difficulties of this type were encountered.

In several instances (specimens #1, #17, #33), curvature of the specimen produced a noticeable strain gradient along the test section. However, these variations from specimen target strain did not affect the analyzed data because the data from each sensor was compared with the strain established by the two strain gages adjacent to each sensor.

Specimen #19 testing was discontinued after 500,000 cycles; an accidental short in the MTS machine servo feedback circuit caused an overload of the specimen. This resulted in damage to the installed gages and failure of the test specimen as shown by Figure 16.

Aside from the instances noted by this paragraph, the testing and collection of data went smoothly and according to the test plan.

2.2 CYCLIC TEMPERATURE TESTS

2.2.1 Introduction

Four specimens (#27, #28, #29, #30) were cycled at four different ambient temperatures with the same constant amplitude load applied. The specimens were instrumented with four fatigue sensors, four strain gages, and two temperature sensors. The specimens were cycled in an environment chamber to produce the required ambient temperature levels (+150°, 80°, 0, -60°F).

2.2.2 Test Specimen

The cyclic temperature test specimen was a 2024-T4 aluminum coupon "dog bone" designed for tension strain only (Figure 17). The specimen was fourteen inches long and the center section was machined to produce a cross sectional area of 0.10 square inches. A one-inch diameter mounting hole was drilled in each end of the specimen.

2.2.3 Instrumentation

Each specimen was instrumented with one FM221-02.5L fatigue sensor on each side (centered). These sensors were flanked by a pair of Micro-Measurements CEA series strain gages (CEA-13-125UW-120) to determine the specimen strain at each fatigue sensor location.

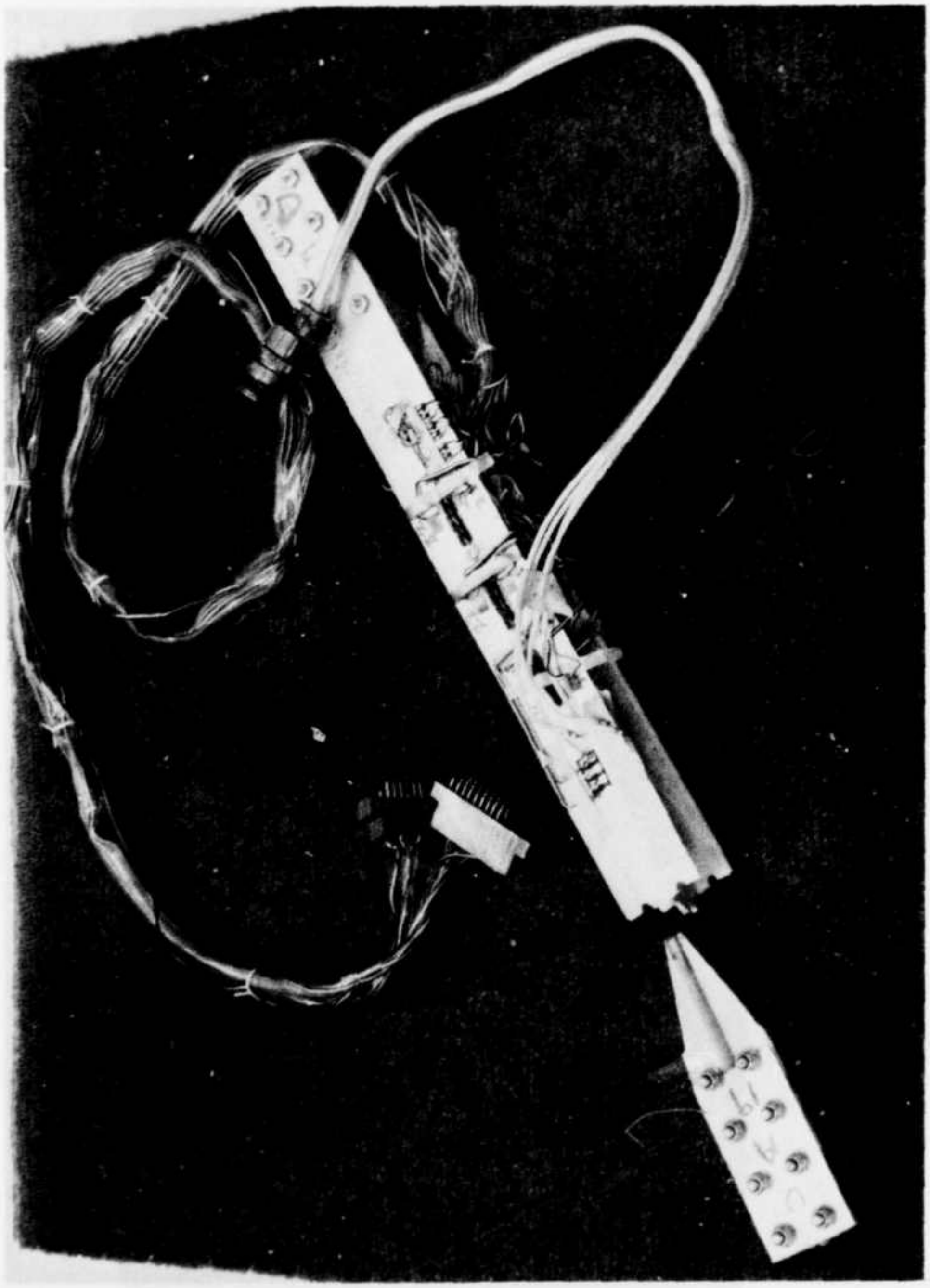


Figure 16 Specimen #19 After Accidental Overload

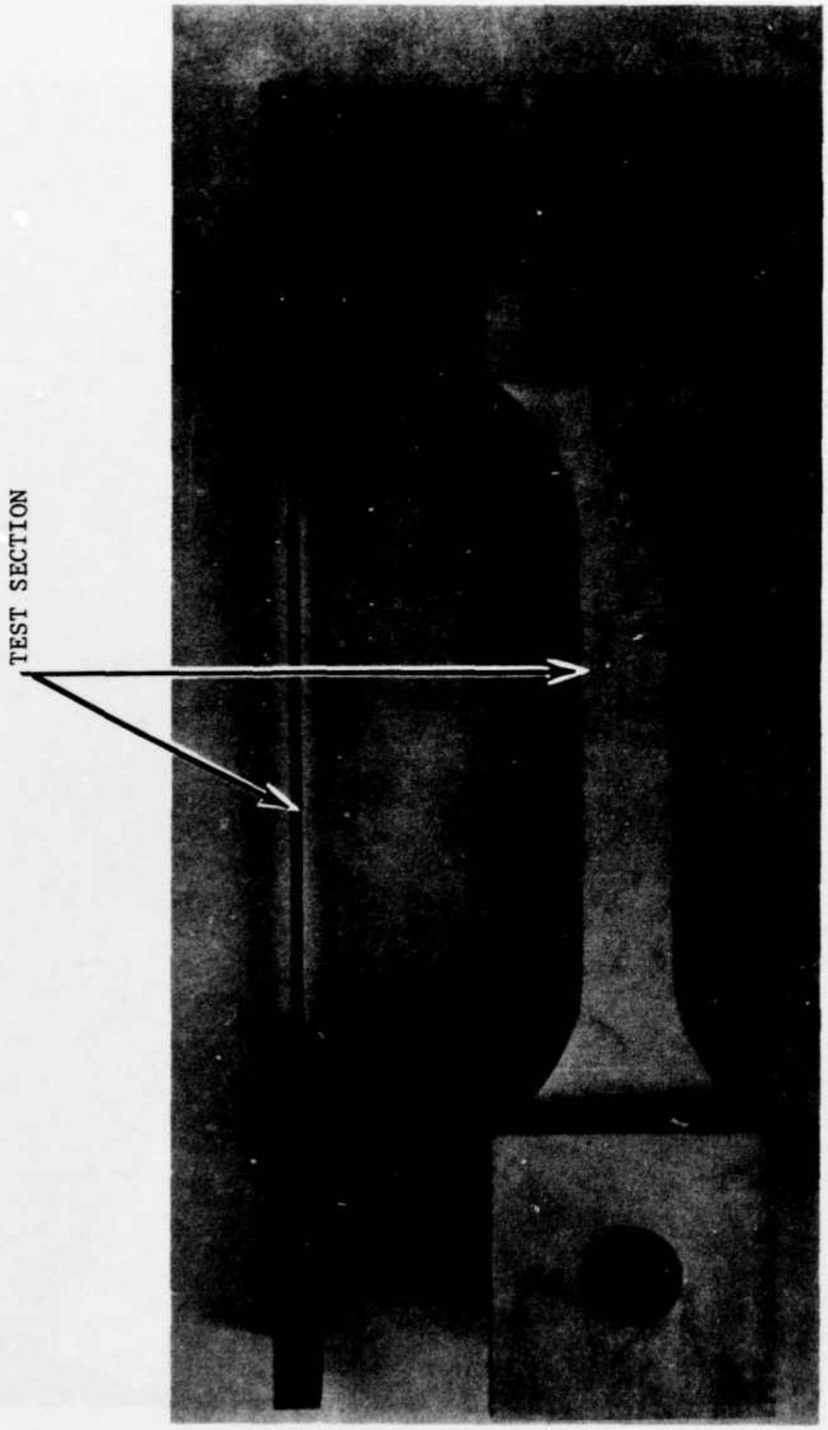


Figure 17 Cyclic Temperature Test Specimen

In addition, an FDA-02 fatigue sensor [8] (unamplified) was installed 1.125 inches from the center of the FM fatigue sensor (on each side). Two Micro-Measurements TG temperature sensors (ETG-50DP) were mounted opposite the FDA sensors. Figures 18 and 19 show the location and identification of all instrumentation on the cyclic temperature test specimen.

The adhesives and procedures used to install the instrumentation are the same as those described for the constant amplitude test specimens (see 2.1.3).

2.2.4 Data Collection System

The data collection system is similar to that described for the constant amplitude tests; however, a small switch box and precision resistor "zero" block were used in lieu of the data collection panel (see 2.1.4). The data readout components are illustrated in Figure 21. Lead wires from the test specimen were routed through the environment chamber wall for hook-up to the switch box and strain indicator.

2.2.5 Test Loads

All specimens were cycled with an alternating strain of ±1000 $\mu\varepsilon$ and a nominal mean strain of +1000 $\mu\varepsilon$ (strain peaks = 0, 2000 $\mu\varepsilon$). Since both the specimen and loading setup were designed for tension only, a "dead band" resulted when a minimum load of zero was used. Consequently, an "offset" of 50 $\mu\varepsilon$ tension was used after 30,000 cycles on specimen #27 and for the other three specimens.

Applied test loads (lbs) were adjusted to produce target strain on the test specimen. All test load adjustments were made at room temperature (80°F) prior to applying the test ambient temperature.

The loading mechanism was designed and fabricated by Cessna. A hydraulic cylinder was mounted outside of the temperature chamber (Figure 21) and connected via a tension link to the loading frame mounted inside the temperature chamber (Figure 20). The hydraulic/servo system used to drive the test was supplied by the Fatigue Master test system used for the A-37 full-scale fatigue tests (Reference 4). Test loads were controlled by a closed loop electro-hydraulic servo system.

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8 Micro-Measurements FDA Sensor - Similar to FM sensor without the multiplier assembly (see Reference 2).

Reference 4. - "A-37B Fatigue Test Control Loading and Data Acquisition System", Cessna Report 318B-6902-121, 25 July 1969.

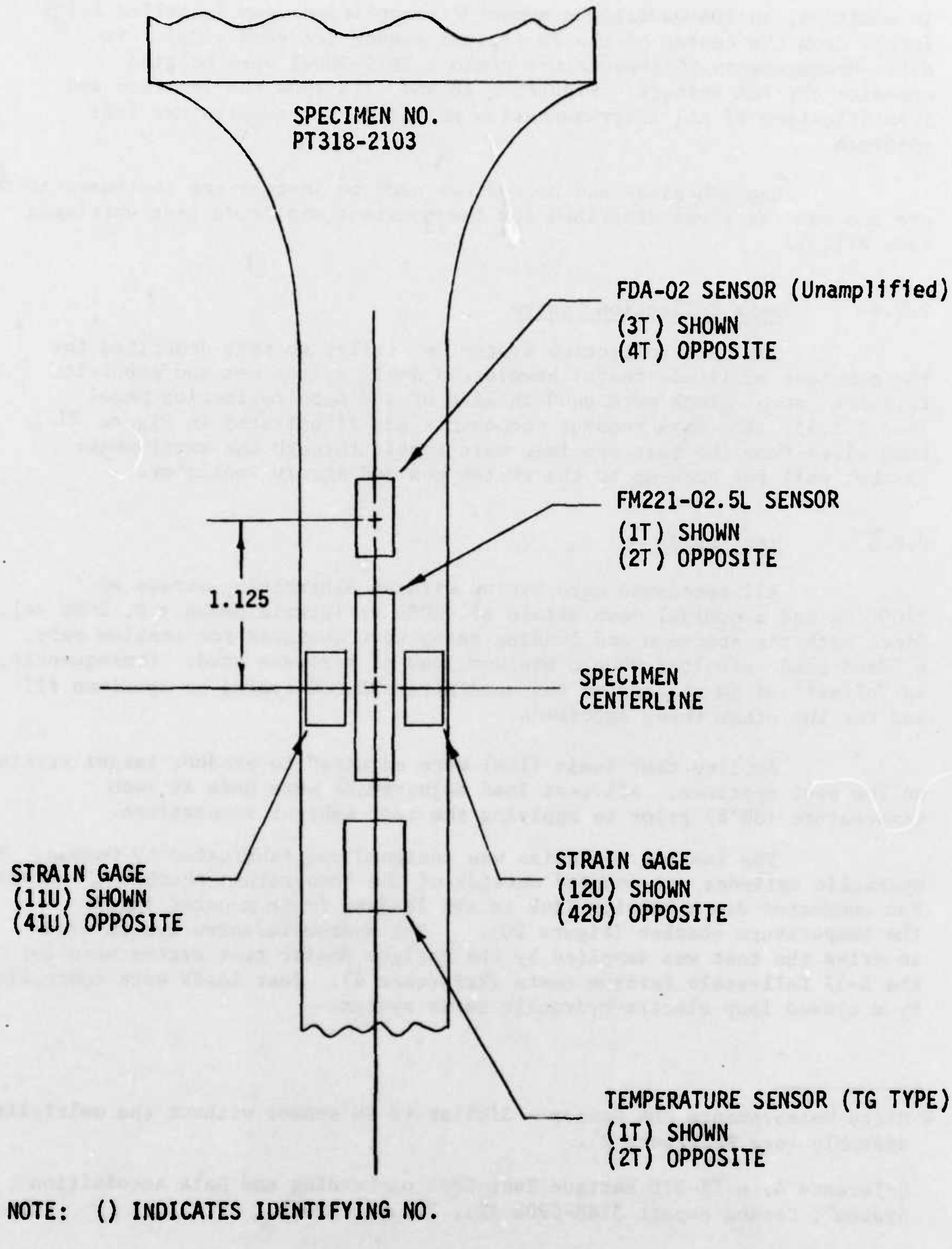


Figure 18 Instrumentation For Cyclic Temperature Coupon

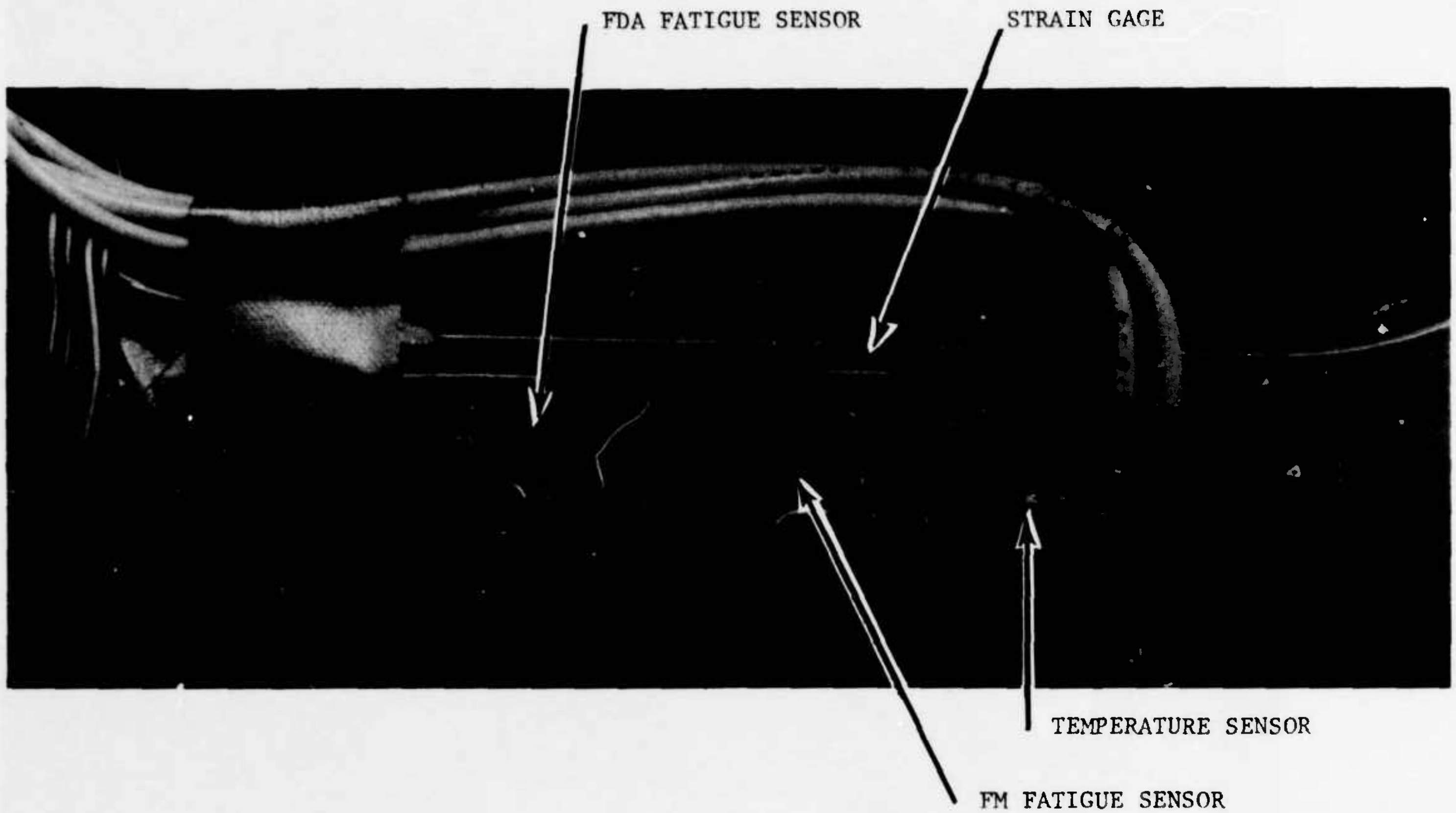


Figure 19 Cyclic Temperature Instrumentation

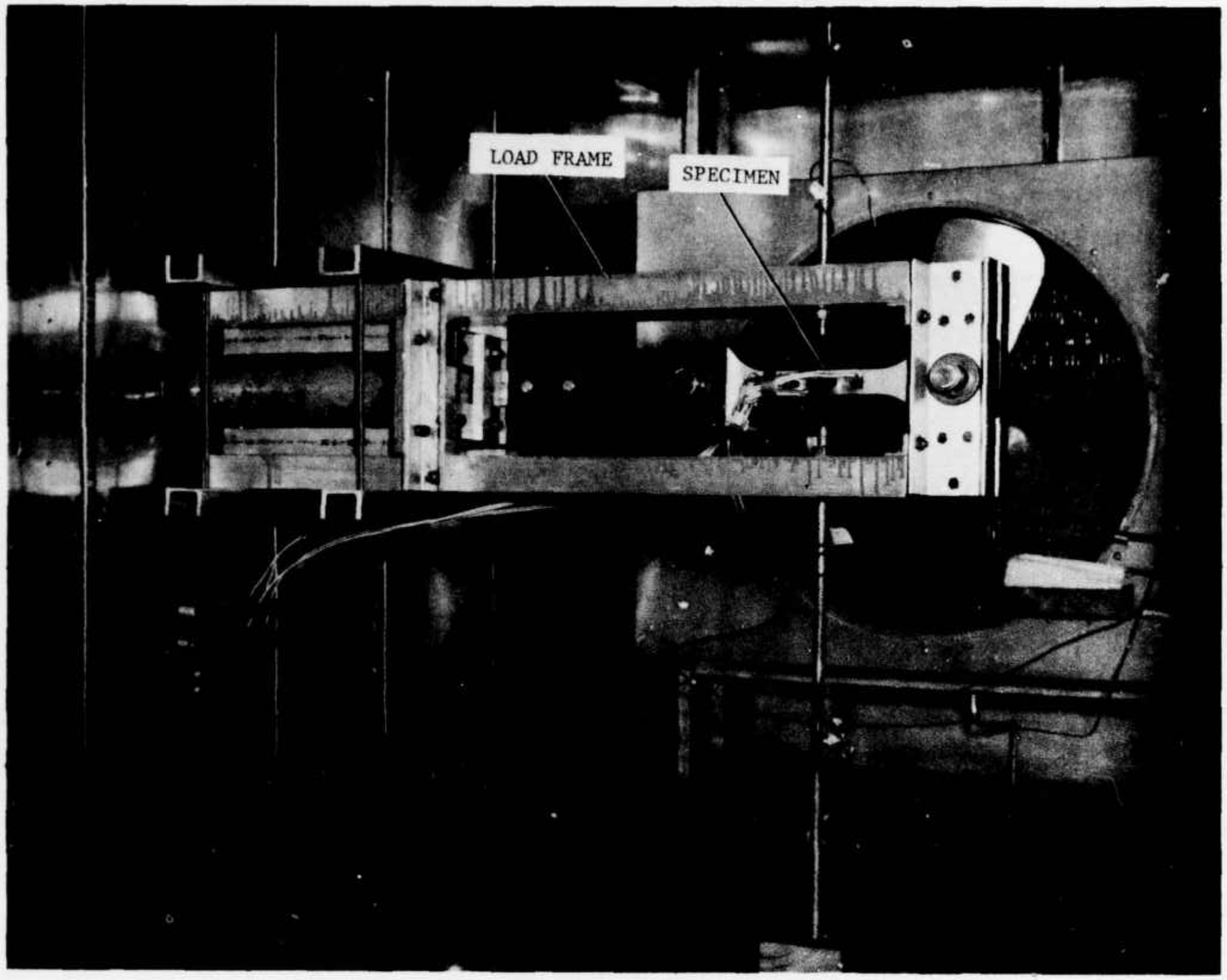


Figure 20 Cyclic Temperature Test Setup, Inside Chamber

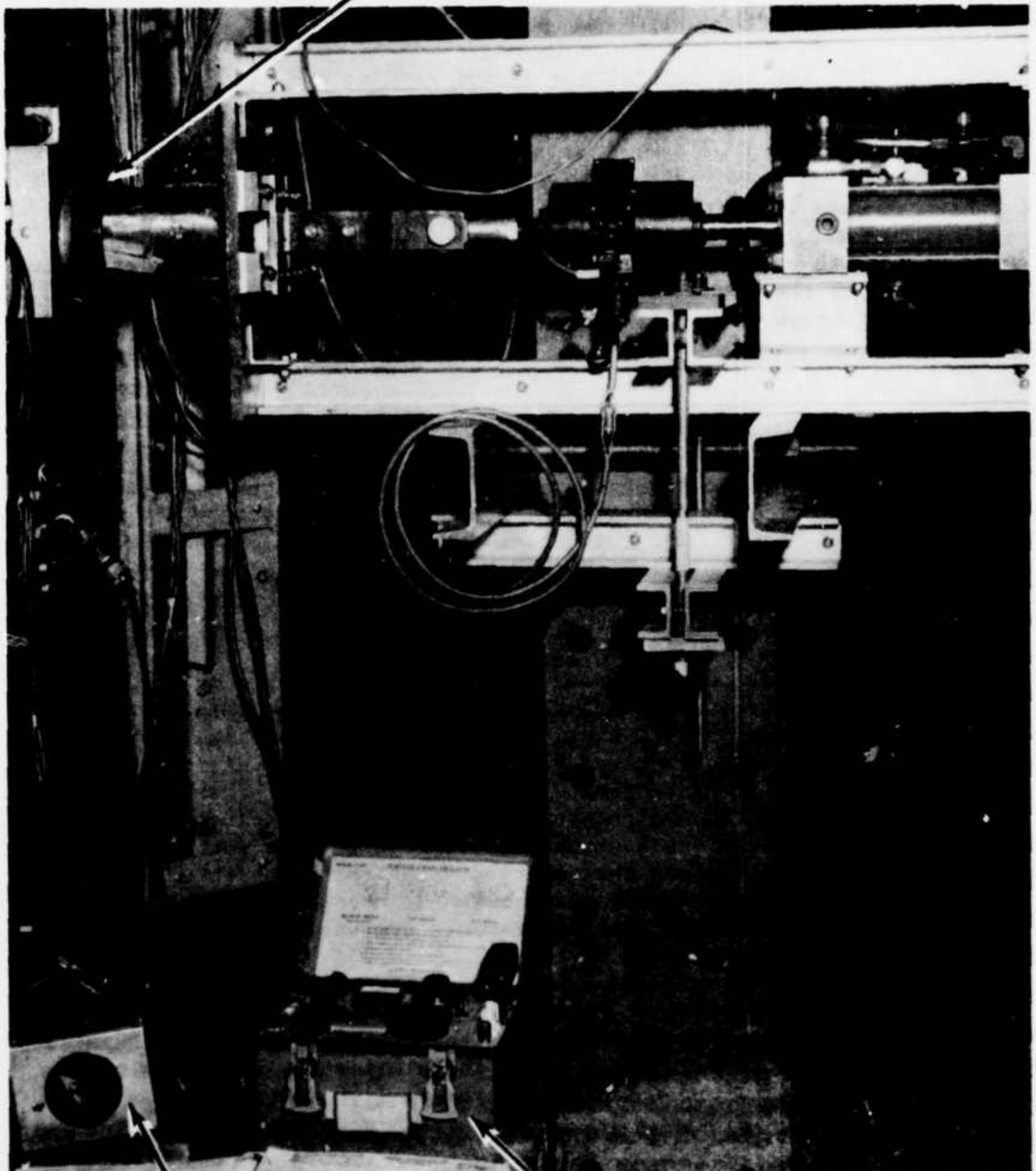


Figure 21   Cyclic Temperature Test Data Collection

2.2.6 Test Data Collected

The test data requirements outlined by paragraph 2.1.6 are applicable to the cyclic temperature tests. The following additional data were collected:

a) The temperature of the environment chamber was recorded continuously.

b) The initial fatigue sensor reading and load cycle response data (zero cycles) were collected at both room temperature and the cyclic ambient temperature.

2.2.7 Data Collection Schedule

Both sensor response and load response data were collected in accordance with the schedule shown in Table 5. In addition, readings were taken at other such intervals as were judged desirable by test personnel.

2.2.8 Test Operation

The test loading frame, which was built for this particular test series, was installed in the environment chamber as shown by Figures 20 and 21. The load frame was designed to extend through the test chamber wall to allow the hydraulic cylinder and servo feedback load cell (Figure 21) to operate at room temperature. The environment chamber used was a Tenney Model No. 64STR-100350.

Cyclic temperature test specimens were mounted in the load frame using one-inch close tolerance pins. Initial zero reading data were collected and an initial static load cycle was then applied to establish the test loads required to produce target strains for that particular specimen (room temperature). The environment chamber was adjusted to the required ambient temperature and the specimen was allowed to stabilize before a second set of zero reading data was collected. Test cycling was then started using the established test loads and required data readings were taken in accordance with the schedule of Table 5. The specimen temperature was maintained for the duration of cycling (±2°F).

A deterioration of multiplier performance was noted at both hot and cold temperature extremes during this test series. To determine the point at which the multiplier began to deteriorate, two tests were conducted upon completion of scheduled cycling (100,000 cycles):

a) Hot multiplier test (specimen #29) - a static load cycle was applied at 80°, 93°, 106°, 132°, and 150°F with data collected per 2.1.6.2.

b) Cold multiplier test (specimen #30) - a static load cycle was applied at 1°, -15°, -31°, -48°, and -61°F with data collected per 2.1.6.2.

2.2.9 Anomalies

The performance of the FM multiplier was found to deteriorate at low temperatures. As originally planned, this test series included three temperature levels (150°, 80°, -60°F). However, due to poor performance of the multiplier during the -60°F test, an additional test was added at 0°F. Normal multiplier performance was demonstrated for 0°F operation.

2.3 AMBIENT TEMPERATURE CYCLE TEST

2.3.1 Introduction

Specimen #26 was subjected to an ambient temperature cycle at 1.0 ohm increments of sensor life. The specimen was cycled using contant amplitude loading to produce resistance change increments of 1.0 ohm. The specimen was placed in an environment chamber and subjected to a temperature cycle of -65° to +125°F; sensor response data were collected at eleven points in the temperature cycle.

2.3.2 Test Specimen

The test specimen was identical to the constant amplitude specimens described by paragraph 2.1.2.

2.3.3 Instrumentation

The test specimen was instrumented with the same configuration as the constant amplitude specimens (see 2.1.3). In addition, two FDA-02 fatigue sensors (unamplified) were added to the web of the test specimen as noted by Figure 4. Figure 22 shows the FDA fatigue sensor installed on the test specimen.

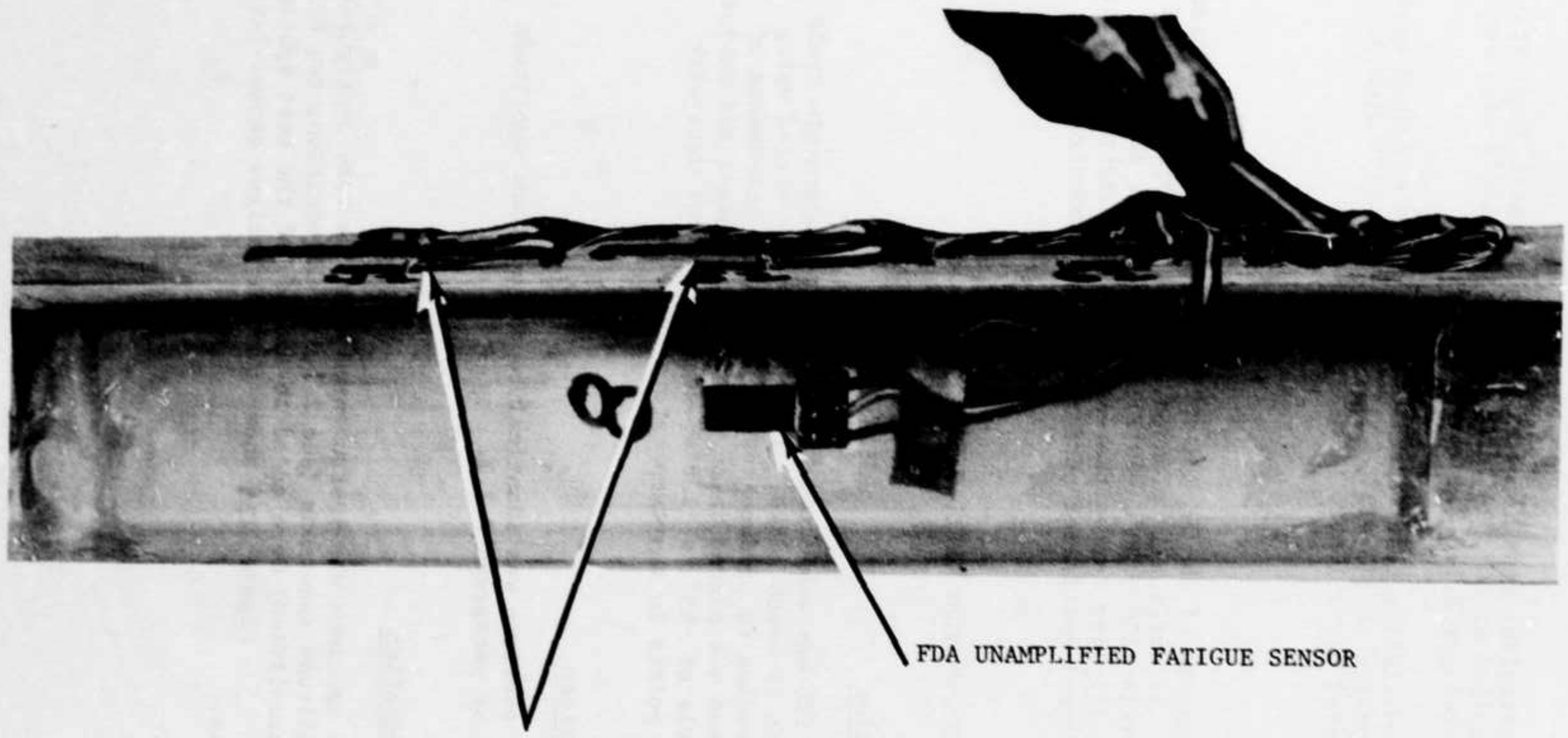


Figure 22 Unamplified Sensor Installation On Specimen #26

2.3.4 Data Collection System

The data collection system described for the constant amplitude tests (see 2.1.4) was used for the ambient temperature cycle test. Lead wires from the specimen were routed through the wall of the environment chamber to the data collection panel (Figure 23).

2.3.5 Test Loads and Temperature Cycles

A constant amplitude load cycle of ±1000 $\mu\varepsilon$ (zero mean strain) was applied to produce 1.0 ohm increments of resistance change on the 2.5 multiplier fatigue sensors. Cycling was accomplished by the MTS test machine used for constant amplitude tests (Figure 10).

The temperature cycles applied to the specimen are shown by Figure 24. The initial cycle (used for first three cycles) was modified due to high temperature creep[h] problems with the FM multiplier assembly (see section 7.7). The final cycle reversed the initial cycle by applying the cold temperatures first and the peak hot temperature was reduced from 150° to 125°F.

The rate of temperature change for temperature cycle application was limited to 20°F/min.

2.3.6 Test Data Collected

Two types of data were collected:

a) Temperature cycle response (resistance change of composite sensor and individual elements due to temperature).

b) Load response (performance of strain multipliers and load compensation under load).

2.3.6.1 Temperature Cycle Response Data

Temperature cycles were applied at approximately 1.0 ohm increments of sensor life (for 2.5 multipliers) as indicated by Table 8. Temperature cycle response data were collected at selected points in the temperature cycle (Figure 24). The following stability criteria were met at each temperature level before data were collected:

[h]High Temperature Creep - Relaxation or slippage of multiplier assembly at high temperature.

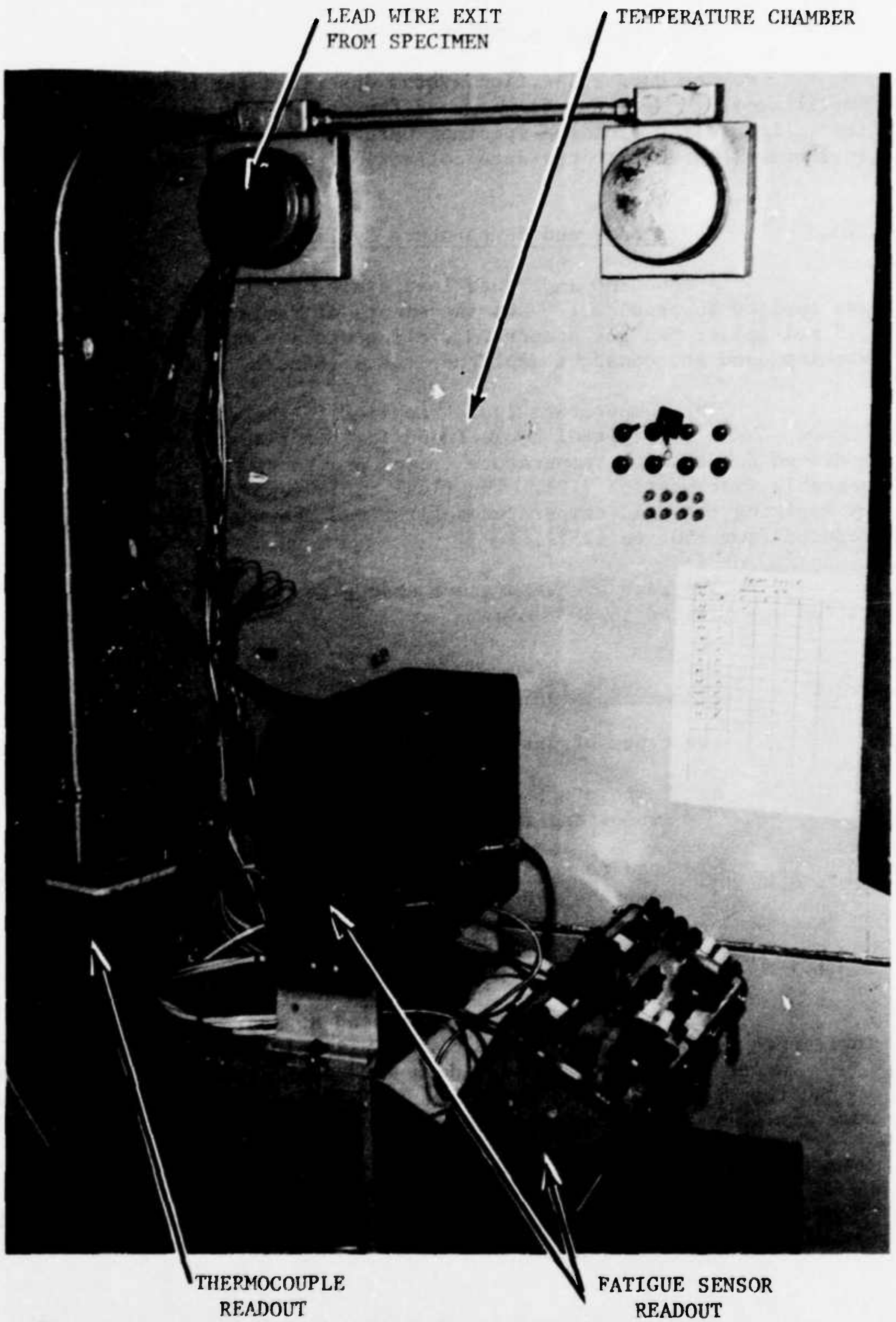


Figure 23 Data Collection Setup For Ambient Temp Test

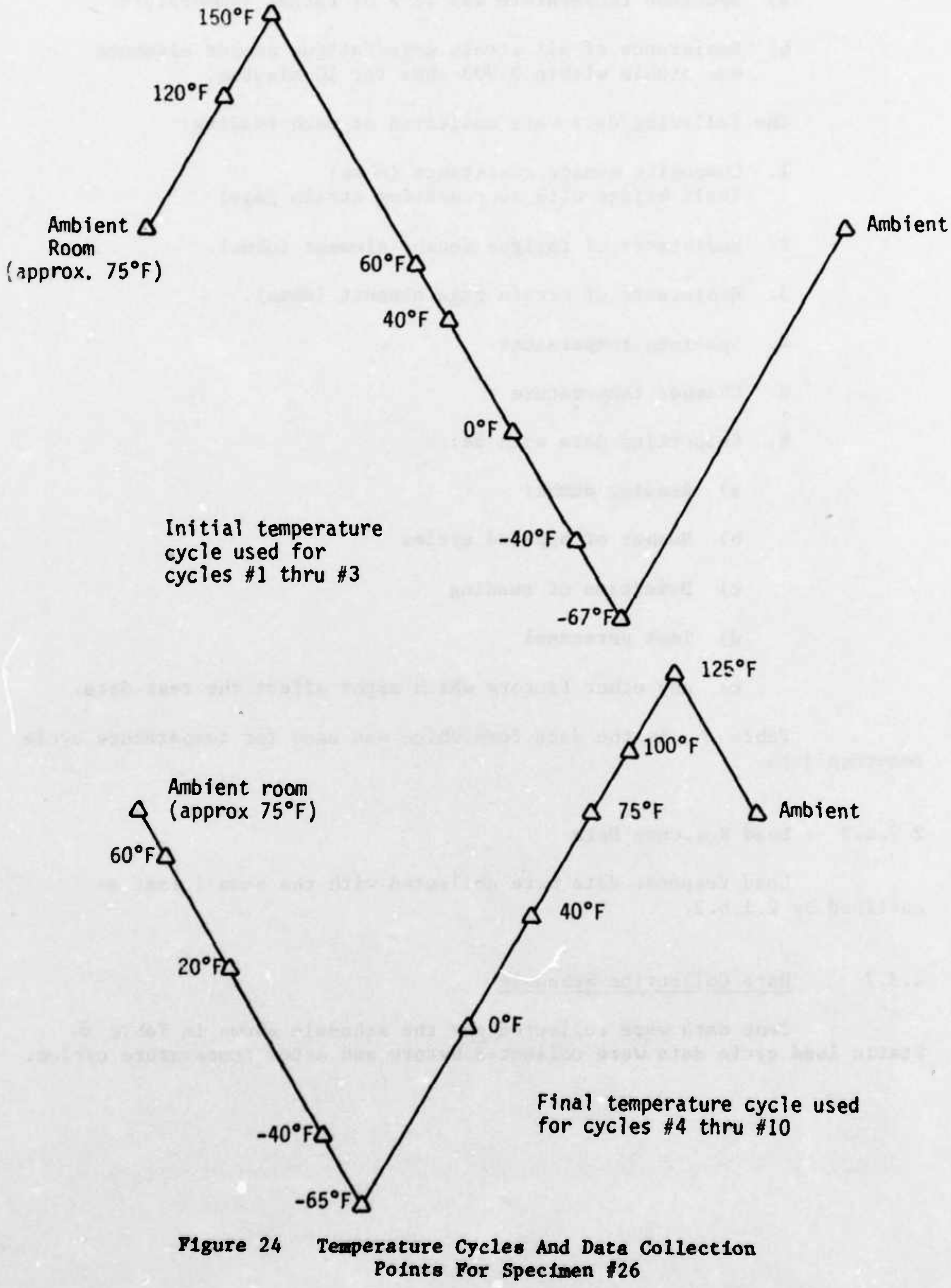


Figure 24 Temperature Cycles And Data Collection Points For Specimen #26

a) Specimen temperature was ±2°F of target temperature.

b) Resistance of all strain gage/fatigue sensor elements was stable within 0.003 ohms for 10 minutes.

The following data were collected at each reading:

1. Composite sensor resistance (ohms) (half bridge with compensating strain gage)

2. Resistance of fatigue sensor element (ohms).

3. Resistance of strain gage element (ohms).

4. Specimen temperature

5. Chamber temperature

6. Supporting data such as:

   a) Reading number

   b) Number of applied cycles

   c) Date/time of reading

   d) Test personnel

   e) Any other factors which might affect the test data.

Table 7 is the data form which was used for temperature cycle response data.

2.3.6.2 Load Response Data

Load response data were collected with the same format as outlined by 2.1.6.2.

2.3.7 Data Collection Schedule

Test data were collected per the schedule shown in Table 8. Static load cycle data were collected before and after temperature cycles.

TABLE 7 SAMPLE DATA COLLECTION FORM TEMPERATURE CYCLE DATA

TEMPERATURE RESPONSE DATA COLLECTION FORM						
ACCUMULATED CYCLES	NOMINAL SENSOR ΔR	DATE	READ BY	CHECK BY	AMBIENT TEMP.	GAGE FACTOR
		TIME				

INDICATED TEMPERATURE	FATIGUE SENSOR DATA							
	SENSOR IDENT.	COMPOSITE (OHMS)	FS ONLY (OHMS)	SG ONLY (OHMS)	SENSOR IDENT.	COMPOSITE (OHMS)	FS ONLY (OHMS)	SG ONLY (OHMS)
CHAMBER =	1U				4U			
T.S. #1 =	2M				5M			
T.S. #2 =	3L				6L			
TIME =	7L				8L			
CHAMBER =	1U				4U			
T.S. #1 =	2M				5M			
T.S. #2 =	3L				6L			
TIME =	7L				8L			

TABLE 8 AMBIENT TEMPERATURE CYCLE DATA COLLECTION SCHEDULE

Read No.	Sensor Resistance Change*	Applied Cycles	Data Required		
			Static Load Cycle Pre-Temp	Temp. Cycle**	Static Load Cycle Post-Temp
Zero	0	0	X	X	X
1	1.019	675	X	X	X
2	2.012	2060	X	X	X
3	2.971	4700	X	X	X
4	3.926	9400	X	X	X
5	4.863	17650	X	X	X
6	5.823	33300	X	X	X

* Average response of 2.5 multiplier sensors (approximate one ohm increments).

** Two temperature cycles were applied at zero ohms and three cycles were applied at one ohm in process of developing a modified temperature cycle (see discussion 2.3.5 and 2.3.8). A total of ten temperature cycles were applied to specimen #26.

2.3.8 Test Operation

The test specimen was installed in the MTS machine (Figure 10) to collect static load cycle data and to load cycle the fatigue sensors. This was accomplished per the schedule of Table 8. The test specimen was cycled until the average resistance change of the 2.5 multiplier/fatigue sensors had reached target 1.0 ohm increments.

When the fatigue sensors reached target resistance changes (ΔR), the test specimen was removed from the MTS machine and placed in the environment chamber. Figures 25 thru 27 show the test specimen positioned in the chamber prior to temperature cycle application. The environment chamber used for this test is the same as that used for the cyclic temperature test (see 2.2.8).

The temperature cycles were applied per Figure 24 ; the specimen was allowed to stabilize at each temperature level prior to collecting fatigue sensor response data.

A modification of the temperature cycle was made after three cycles had been applied; high temperature creep of the FM multiplier assembly caused a discontinuity in data. The temperature cycle was modified to apply the cold half of the cycle first and the peak hot temperature was reduced from 150° to 125°F (see Figure 24).

2.4 SPECTRUM LOADED TESTS

2.4.1 Introduction

Specimens #24 and #25 were cycled under spectrum loads. Each specimen was subjected to the identical load cycles but the order of application was scrambled using a series of 10 high level and 24 low level "flights". Fatigue sensor, strain gage, and temperature data were collected at selected intervals to produce required sensor response data.

2.4.2 Test Specimen

The test specimen was identical to that of constant amplitude test series (see 2.1.2).

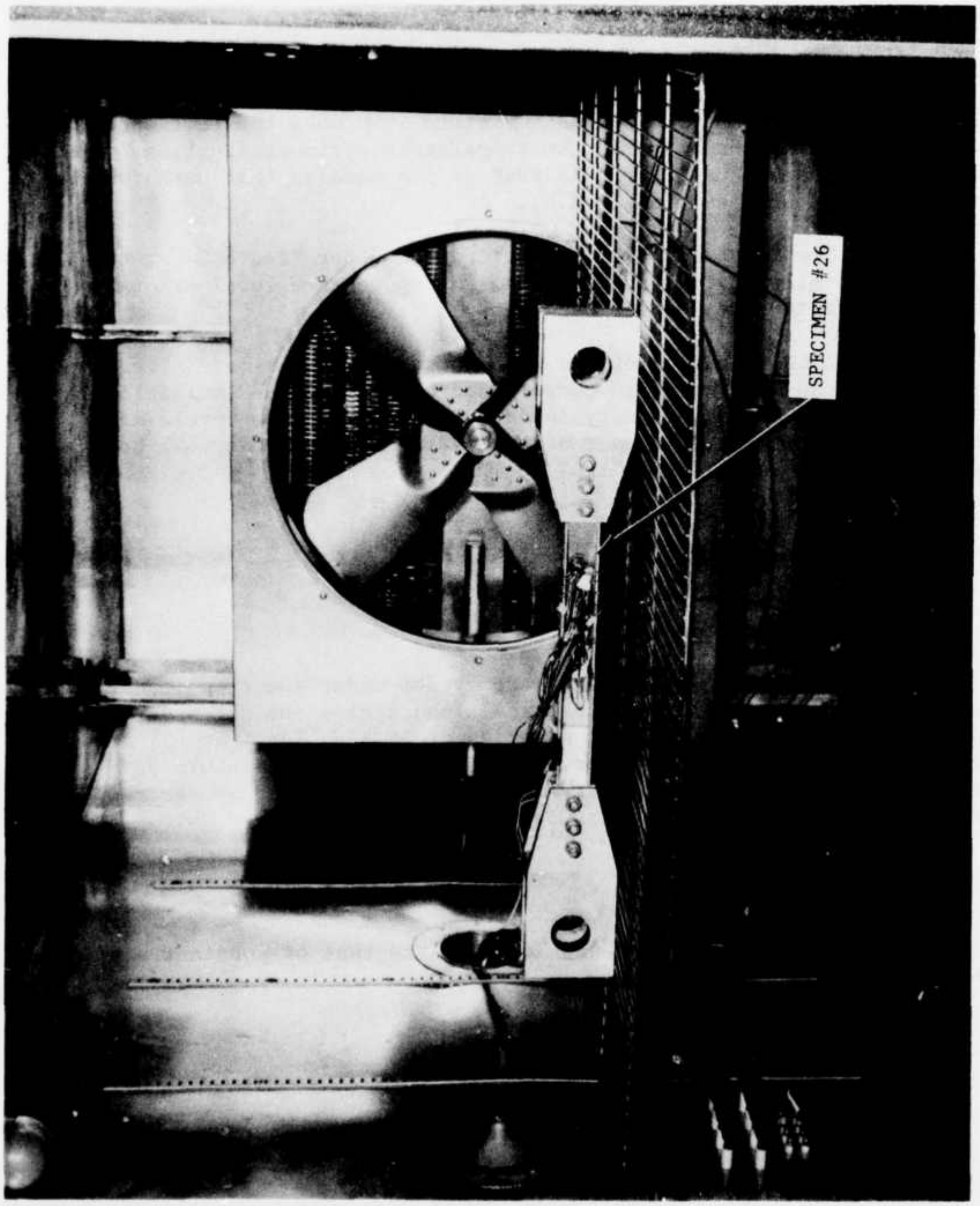


Figure 25 Ambient Temp Cycle Test Setup

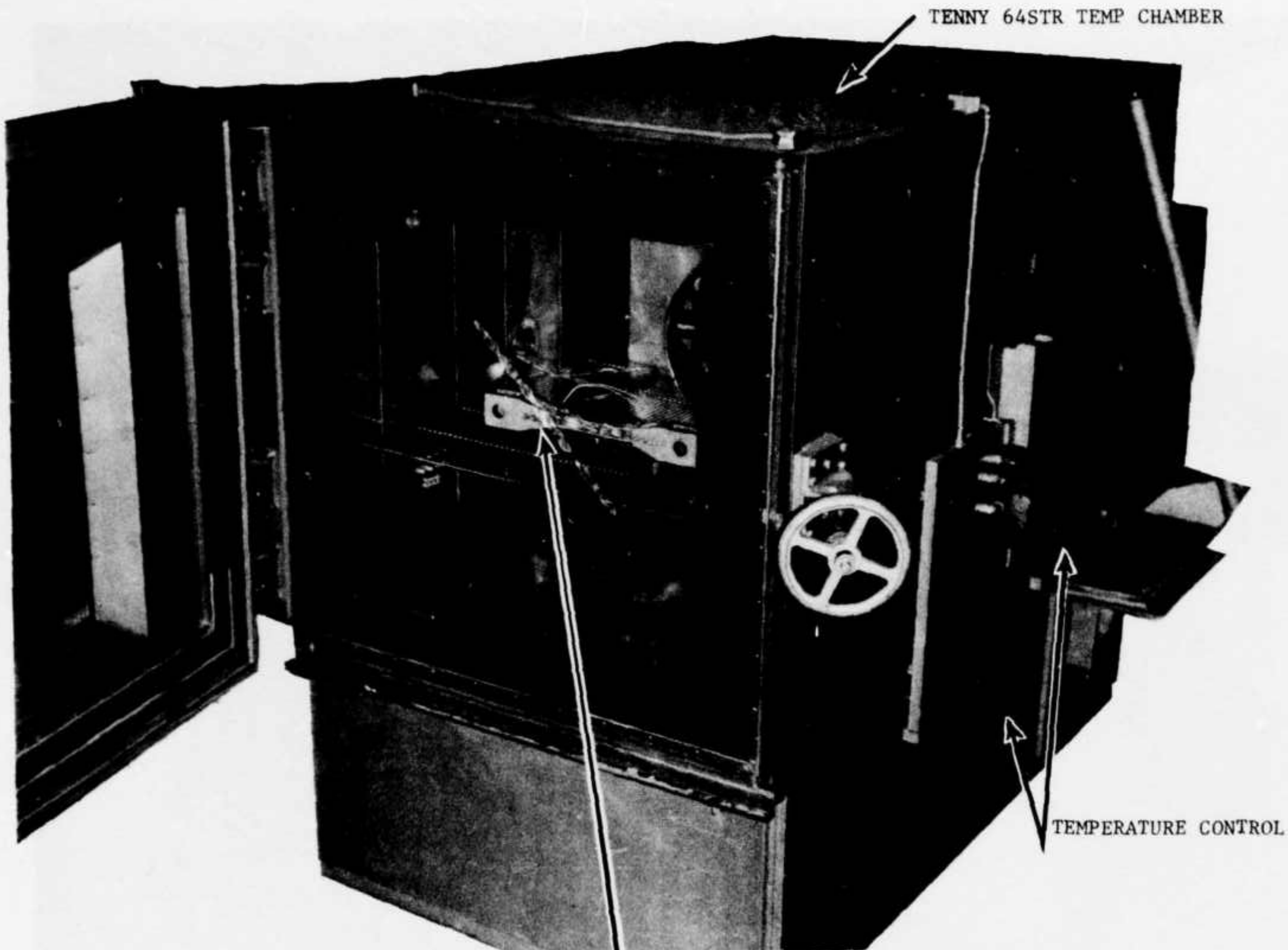


Figure 26 Ambient Temperature Cycle Test

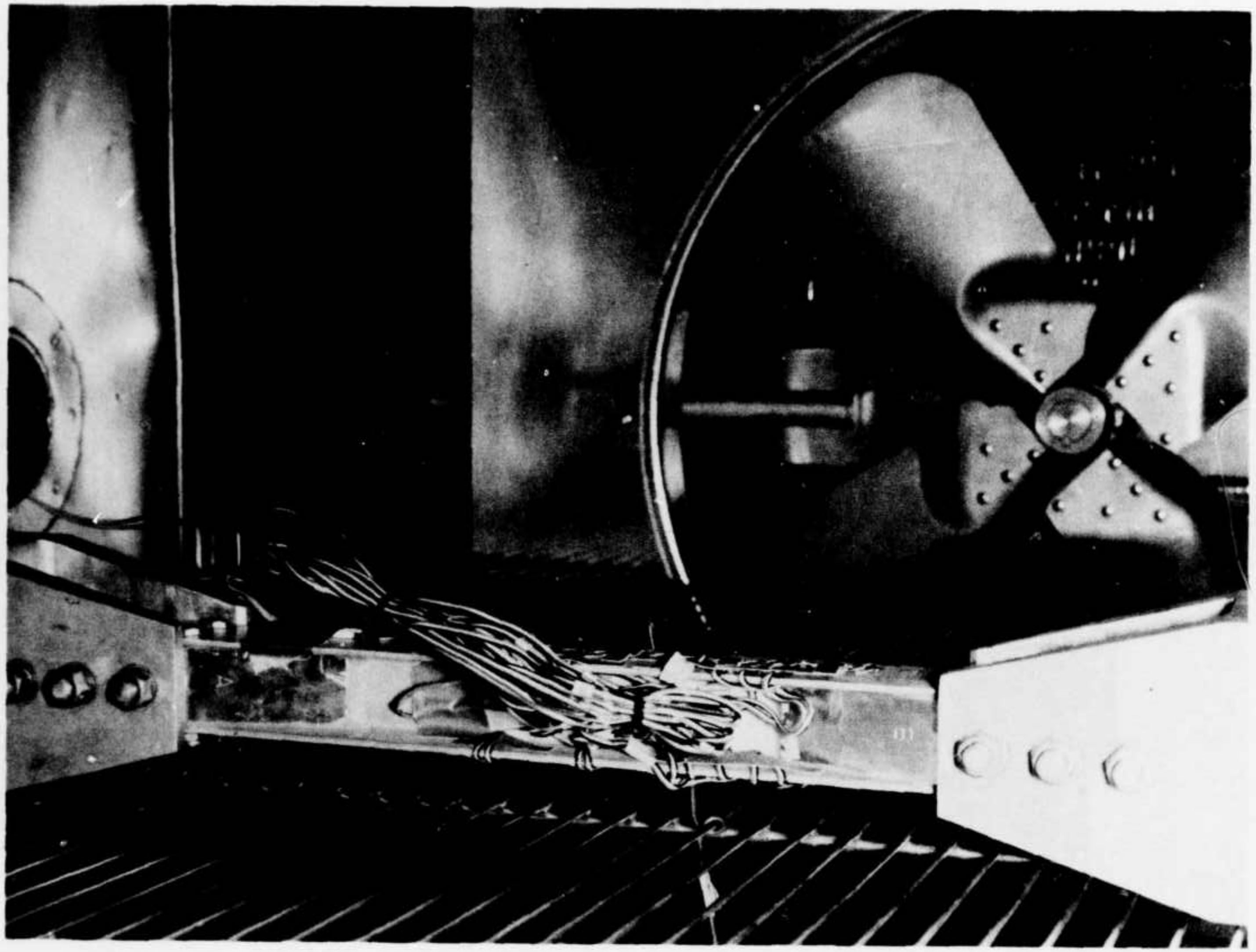


Figure 27 Ambient Temperature Test Setup

2.4.3 Instrumentation

Spectrum loaded specimens were instrumented with the same configuration as described for constant amplitude tests (see 2.1.3 and Figures 3 thru 6).

2.4.4 Data Collection System

The data collection system was identical to that of the constant amplitude tests (see 2.1.4).

2.4.5 Test Loads

Two load spectrums for specimens #24 and #25 were developed using typical A-37 strain cycles recorded by mechanical strain gages at England AFB (Reference 5). Strain cycles were grouped into two sets of cycles according to "high severity" and "low severity" usage. Table 9 lists the 29 load levels of high severity and Table 10 lists the 14 load levels of low severity. These load levels were applied in random order to the two specimens with a series of 34 flights (10 high, 24 low severity). Tables 11 and 12 list the order of cycle application for each flight. The flights were applied to each specimen in ascending alphabetical order per Table 13 . One repeatable layer of cycling consisted of the complete application of <u>either</u> the high severity flights or low severity flights with a total of 300 cycles per layer. The application of spectrum type (high or low severity) was alternated throughout the test as defined by Table 14 .

Figure 29 shows an oscillograph trace of the high and low severity spectrums applied to specimen #25. The initial "flight" application is identified in each case.

2.4.6 Test Data Collected

The test data requirements outlined by paragraph 2.1.6 are applicable to the spectrum loaded tests. However, both the data collection schedule and load response cycle were modified for spectrum loaded specimens:

Reference 5. - "A-37B Aircraft Scratch Gage Field Evaluation", Cessna Report 318E-7219-023, 15 May 1972.

TABLE 9 LOAD LEVELS, HIGH SEVERITY

High severity flight load levels based on A-37B ground attack and acrobatics missions.

Load Block No.	Alt. Strain (με)	Mean Strain (με)	Max. Strain (με) ⚠1	Min. Strain (με) ⚠1	App. Cycles
H1	±400	-400	0	-800	1
H2	±400	-200	+200	-600	1
H3	±400	0	+400	-400	2
H4	±400	+600	+1000	+200	7
H5	±400	+800	+1200	+400	4
H6	±450	-200	+250	-650	1
H7	±450	0	+450	-450	1
H8	±450	+200	+650	-250	4
H9	±450	+400	+850	-50	1
H10	±450	+600	+1050	+150	6
H11	±450	+800	+1250	+350	1
H12	±500	-400	+100	-900	1
H13	±500	0	+500	-500	2
H14	±500	+200	+700	-300	1
H15	±500	+600	+1100	+100	6
H16	±500	+800	+1300	+300	1
H17	±550	+200	+750	-350	4
H18	±550	+400	+950	-150	1
H19	±550	+600	+1150	+50	1
H20	±550	+800	+1350	+250	1
H21	±550	+1000	+1550	+450	1
H22	±600	0	+600	-600	2
H23	±600	+200	+800	-400	2
H24	±600	+600	+1200	0	1
H25	±600	+800	+1400	+200	2
H26	±650	+200	+850	-450	2
H27	±650	+800	+1450	+150	1
H28	±700	+200	+900	-500	1
H29	±750	+800	+1550	+50	1
High Severity Flight Total Cycles =					60

⚠1 Applied specimen loads were adjusted to achieve target strain values (±5%).

TABLE 10 LOAD LEVELS, LOW SEVERITY

Low severity flight load levels based on A-37B navigation and formation missions.

Load Block No.	Alt. Strain (με)	Mean Strain (με)	Max. Strain (με) ⚠1	Min. Strain (με) ⚠1	App. Cycles
L1	±400	-400	0	-800	1
L2	±400	-200	+200	-600	1
L3	±400	0	+400	-400	1
L4	±400	+200	+600	-200	1
L5	±400	+400	+800	0	2
L6	±400	+600	+1000	+200	6
L7	±450	0	+450	-450	1
L8	±450	+400	+850	-50	1
L9	±450	+600	+1050	+150	4
L10	±500	0	+500	-500	1
L11	±500	+200	+700	-300	2
L12	±500	+600	+1100	+100	1
L13	±550	0	+550	-550	2
L14	±600	0	+600	-600	1
Low Severity Flight Total Cycles =					25

⚠1 Applied specimen loads were adjusted to achieve target strain values (±5%).

TABLE 11 LOAD APPLICATION ORDER FOR HIGH SEVERITY FLIGHTS
(ALL LOAD LEVELS STARTING WITH LETTER H)

	SPECIMEN #24					SPECIMEN #25				
FLT. IDENT.	HA	HB	HC	HD	HE	HF	HG	HH	HI	HJ
LOAD BLOCK NUMBERS PER TABLE 9	H10	H10	H24	H14	H29	H17	H17	H13	H18	H17
	H24	H22	H12	H1	H3	H11	H8	H24	H11	H22
	H29	H6	H25	H25	H1	H7	H13	H29	H1	H6
	H20	H23	H18	H16	H21	H21	H21	H11	H21	H21
	H27	H18	H1	H2	H15	H20	H23	H12	H4	H14
	H2	H1	H2	H4	H10	H8	H26	H7	H20	H25
	H11	H29	H23	H21	H14	H10	H25	H23	H12	H12
	H3	H8	H7	H22	H17	H29	H19	H21	H7	H9
	H19	H21	H27	H26	H13	H5	H14	H26	H28	H15
	H17	H13	H6	H6	H5	H18	H2	H9	H16	H19
	H13	H26	H26	H19	H12	H12	H15	H15	H3	H7
	H8	H24	H9	H20	H9	H16	H6	H1	H15	H18
	H9	H15	H10	H3	H23	H28	H5	H19	H5	H13
	H15	H2	H20	H17	H18	H6	H29	H22	H6	H11
	H6	H4	H14	H13	H28	H23	H12	H6	H22	H20
	H12	H5	H21	H29	H25	H13	H7	H18	H13	H1
	H26	H12	H19	H24	H20	H2	H20	H14	H29	H3
	H5	H25	H15	H10	H6	H4	H1	H16	H23	H2
	H4	H3	H13	H28	H7	H9	H9	H3	H9	H24
	H22	H7	H11	H8	H2	H1	H4	H17	H2	H27
	H16	H27	H29	H12	H8	H14	H10	H27	H24	H23
	H21	H17	H17	H15	H16	H3	H22	H2	H19	H5
	H18	H16	H4	H23	H4	H24	H16	H28	H14	H10
	H25	H11	H28	H18	H27	H22	H18	H8	H25	H28
	H7	H20	H5	H7	H26	H25	H24	H10	H8	H16
	H23	H9	H22	H9	H22	H15	H3	H20	H26	H8
	H14	H28	H3	H27	H19	H27	H11	H25	H17	H4
	H1	H14	H8	H5	H11	H19	H28	H4	H10	H26
	H28	H19	H16	H11	H24	H26	H27	H5	H27	H29

TABLE 12 LOAD APPLICATION ORDER FOR LOW SEVERITY FLIGHTS
(ALL LOAD LEVELS STARTING WITH LETTER L)

SPECIMEN #24

FLT. IDENT.	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ	LK	LL
LOAD BLOCK NUMBERS PER TABLE 10	L2	L12	L3	L5	L6	L13	L14	L3	L3	L7	L8	L7
	L5	L2	L5	L11	L11	L1	L1	L1	L12	L6	L14	L2
	L3	L8	L12	L2	L2	L8	L10	L10	L1	L12	L2	L14
	L6	L7	L13	L12	L4	L9	L13	L7	L10	L1	L10	L13
	L14	L4	L14	L7	L8	L12	L2	L14	L8	L14	L1	L3
	L8	L3	L1	L6	L9	L10	L4	L13	L14	L8	L6	L5
	L12	L6	L11	L14	L5	L7	L8	L5	L11	L11	L9	L8
	L7	L11	L7	L1	L1	L6	L5	L12	L13	L10	L12	L9
	L9	L5	L6	L4	L12	L4	L6	L4	L7	L13	L11	L4
	L1	L9	L8	L8	L10	L3	L7	L11	L4	L9	L7	L11
	L11	L1	L4	L3	L3	L5	L12	L9	L6	L5	L4	L1
	L4	L14	L2	L13	L14	L11	L11	L2	L5	L3	L5	L10
	L13	L13	L9	L9	L7	L2	L9	L6	L2	L4	L13	L6
	L10	L10	L10	L10	L13	L14	L3	L8	L9	L2	L3	L12

SPECIMEN #25

FLT. IDENT.	LM	LN	LO	LP	LQ	LR	LS	LT	LU	LV	LW	LX
LOAD BLOCK NUMBER PER TABLE 10	L2	L14	L7	L5	L10	L13	L10	L8	L9	L1	L6	L1
	L8	L4	L9	L8	L14	L11	L3	L14	L8	L8	L11	L9
	L1	L12	L8	L7	L12	L6	L12	L1	L1	L11	L9	L2
	L7	L10	L14	L10	L7	L8	L8	L12	L10	L6	L2	L3
	L12	L2	L2	L13	L1	L12	L14	L5	L13	L4	L8	L10
	L10	L8	L6	L11	L9	L1	L11	L3	L7	L10	L3	L14
	L5	L1	L10	L3	L5	L3	L4	L4	L14	L7	L12	L4
	L3	L6	L1	L2	L8	L10	L13	L13	L12	L5	L13	L8
	L13	L7	L12	L6	L13	L14	L6	L6	L11	L9	L5	L11
	L6	L3	L13	L12	L3	L9	L1	L7	L6	L13	L14	L6
	L4	L11	L4	L4	L4	L7	L9	L2	L3	L3	L1	L13
	L14	L13	L5	L14	L11	L5	L2	L11	L4	L14	L10	L7
	L9	L9	L3	L9	L6	L2	L5	L9	L2	L2	L4	L12
	L11	L5	L11	L1	L2	L4	L7	L10	L5	L12	L7	L5

TABLE 13 FLIGHT APPLICATION ORDER FOR ONE LAYER

Specimen #24		Specimen #25	
High Severity	Low Severity	High Severity	Low Severity
HA	LA	HF	LM
HB	LB	HG	LN
HC	LC	HH	LO
HD	LD	HI	LP
HE	LE	HJ	LQ
	LF		LR
	LG		LS
	LH		LT
	LI		LU
	LJ		LV
	LK		LW
	LL		LX

1. One layer consisted of either:

   a) 5 high severity flights

   or b) 12 low severity flights

2. Total cycles for each layer = 300 with either:

   a) 60 cycles/high severity flight

   or b) 25 cycles/low severity flight

TABLE 14 FLIGHT APPLICATION SCHEDULE FOR SPECIMENS #24 AND #25

No. Of Layers Applied	Applied Cycles	Accumulated Cycles	Type Of Flight (Severity)
2	600	600	High
6	1800	2400	Low
12	3600	6000	High
60	18000	24000	Low
120	36000	60000	High
600	180000	240000	Low
2533	759900	999900	High

Total Layers = 3,333
Total Cycles = 999,900

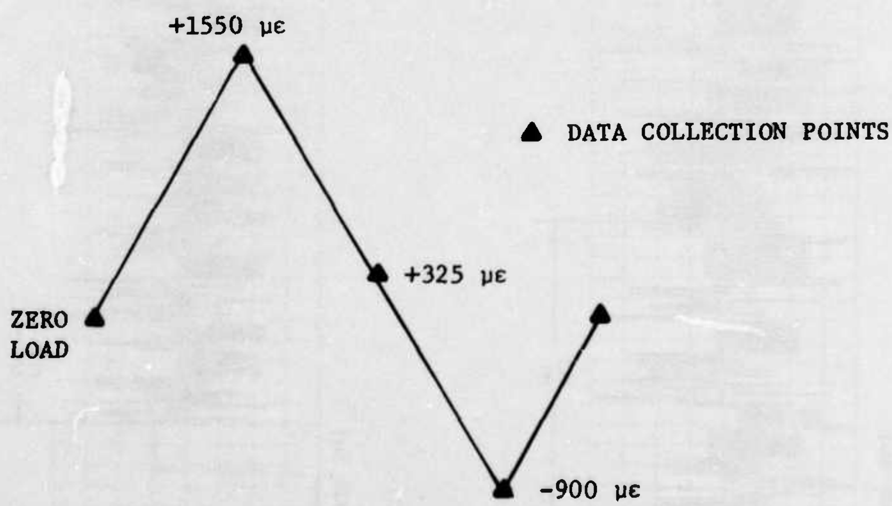
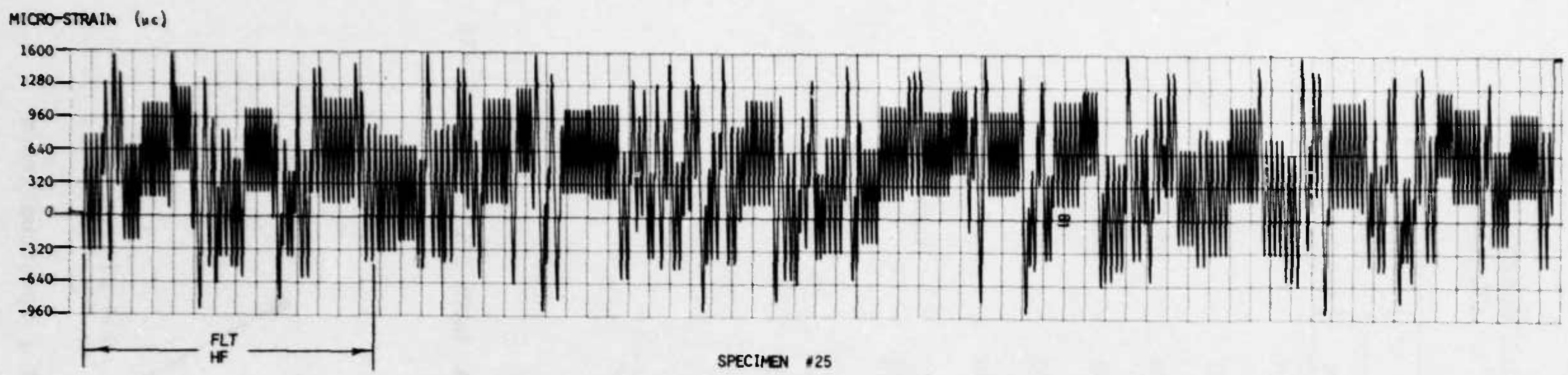
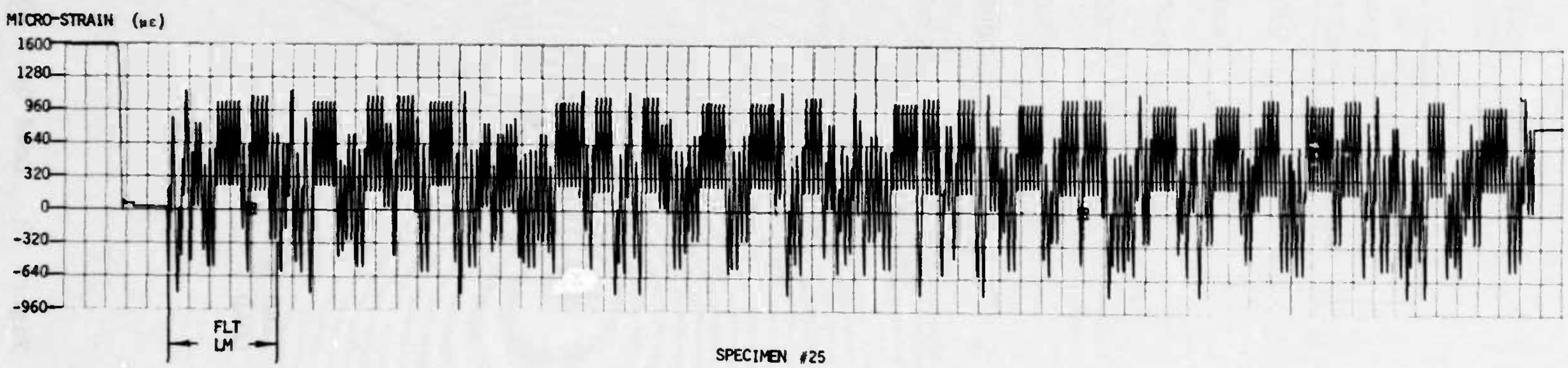


Figure 28 Load Cycle Data Points For Spectrum Tests



SPECIMEN #25

ONE LAYER HIGH SEVERITY FLIGHT



SPECIMEN #25

ONE LAYER LOW SEVERITY FLIGHT

Figure 29 Oscillograph Trace Of Load Spectrum For Specimen #25

a) Data collection schedule - Table 15 defines the data collection schedule for spectrum loaded specimens.

b) Load response cycle - Load response data were collected at selected intervals using the strain cycle and data collection points of Figure 28.

Also an oscillograph printout of the load spectrum (one layer) was obtained for each specimen (see Figure 29).

2.4.7 <u>Data Collection Schedule</u>

Both sensor response and load response data were collected in accordance with Table 15. In addition, readings were taken at other such intervals as were judged desirable by test personnel.

2.4.8 <u>Test Operation</u>

The spectrum loaded tests were operated with the same procedure as constant amplitude tests. For cyclic spectrum loading, a punched tape drive was used to set load levels. The MTS tape reader and digital block programmer[1] (Figure 10) were used to feed the tape information to the MTS loading system. The initial static load cycle was used to adjust applied load levels (lbs) to produce target specimen strain ($\mu\varepsilon$).

2.5 TEMPERATURE INDUCED CYCLE TEST

2.5.1 <u>Introduction</u>

Two specimens (#31 and #32) were subjected to 50 temperature cycles with no mechanical strain applied. The specimens were temperature cycled in the environment chamber from +150°F to -50°F. Fatigue sensor response and induced strain cycle data were collected at selected intervals.

2.5.2 <u>Test Specimens</u>

The test specimens consisted of two different metal plates with different thermal expansion rates:

---

[1]Digital Block Programmer - System for conversion of digital tape information into machine command signal.

TABLE 15 DATA COLLECTION SCHEDULE

Data was collected for each spectrum loaded specimen per this schedule until:

a) All fatigue sensors were open circuit or $\Delta R = 8$ ohms

or b) Applied specimen cycles reached 999,900.

Read No.	Applied Cycles	Layers Appl.	Type Data	
			Sensor	Load
ZERO	0	0	X	X
1	10		X	
2	25		X	
3	50		X	
4	100		X	X
5	150		X	
6	200		X	
7	300	1	X	
8	450		X	
9	600	2	X	
10	900	3	X	X
11	1200	4	X	
12	1800	6	X	
13	2700	9	X	X
14	4200	14	X	
15	6000	20	X	
16	9000	30	X	X
17	13500	45	X	
18	19500	65	X	
19	24600	82	X	
20	30000	100	X	X
21	39000	130	X	
22	49500	165	X	
23	64500	215	X	
24	79500	265	X	
25	99900	333	X	X
26	150000	500	X	
27	199500	665	X	
28	249000	830	X	
29	300000	1000	X	X
30	405000	1350	X	
31	495000	1650	X	
32	750000	2500	X	
33	999900	3333	X	X

a) Specimen #31 - 2024-T4 Aluminum Thermal Coff. = 12.9 PPM/°F[3]

b) Specimen #32 - 316 Stainless Steel Thermal Coff. = 8.8 PPM/°F

Figure 30 shows the dimensions for each specimen; specimen dimensions were tailored to give 50% the volume of stainless steel for aluminum. This produced approximately the same heating and cooling rate for each specimen.

2.5.3 Instrumentation

The aluminum specimen (#31) was instrumented with six FM fatigue sensors, two FDA fatigue sensors, two TG temperature sensors, and one thermocouple. The stainless steel specimen (#32) was instrumented with four FDA fatigue sensors, two TG temperature sensors, and one thermocouple. The location and identification of all instrumentation are shown by Figures 31 and 32.

2.5.4 Data Collection System

The data collection system described for the constant amplitude tests (see 2.1.4) was used for the temperature induced cycle test. Lead wires from the specimens were routed through the wall of the environment chamber to the data collection panel (Figure 23). Thermocouples were read with a portable pyrometer potentiometer.

2.5.5 Tests Loads

Test loads consisted of 50 strain cycles induced by temperature (no mechanical strain applied). Each temperature cycle was an excursion from +150°F to -50°F with 50°F used as a starting and ending point for each cycle (Figure 33). The following temperature stability criteria were met at each temperature peak of the cycle before changing to the opposite temperature peak:

a) Specimen temperature was ±2°F of target temperature (±150°F, -50°F).

b) Resistance of all strain gage/fatigue sensor elements was stable within 0.003 ohms for ten minutes.

The temperature change rate was limited to 20°F/minute in transition between maximum and minimum temperatures.

Temperature cycles were applied by the environment chamber used for other temperature tests (reference section 2.2 and 2.3).

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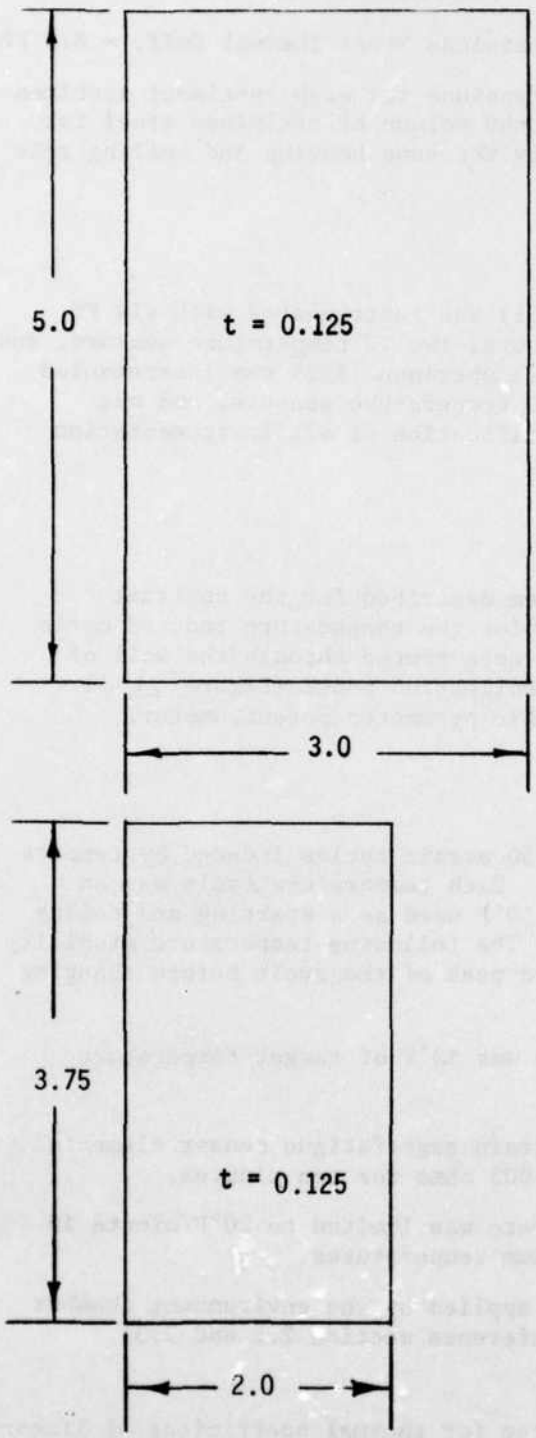
[3] PPM/°F - Parts per million per degree for thermal coefficient of linear expansion.



SPECIMEN NO. 31

2024-T3 ALUMINUM PLATE
THERMAL EXPANSION COEFFICIENT = 12.9 PPM

SPECIMEN NO. 32

316 STAINLESS STEEL PLATE
THERMAL EXPANSION COEFFICIENT = 8.8 PPM

Figure 30 **Specimen Configuration For Temperature Induced Cycle Test**

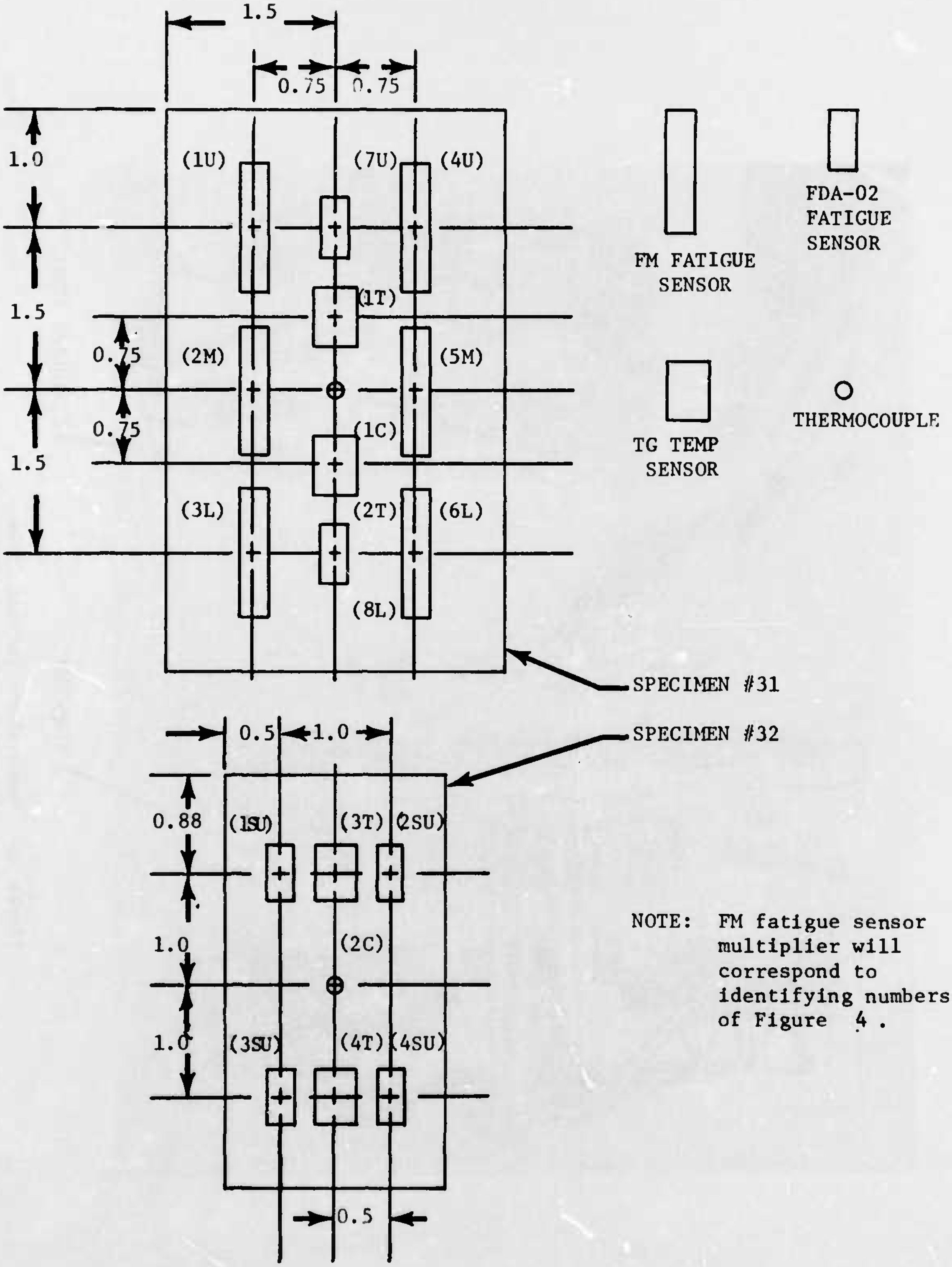


Figure 31 Instrumentation For Temperature Induced Cycle Test

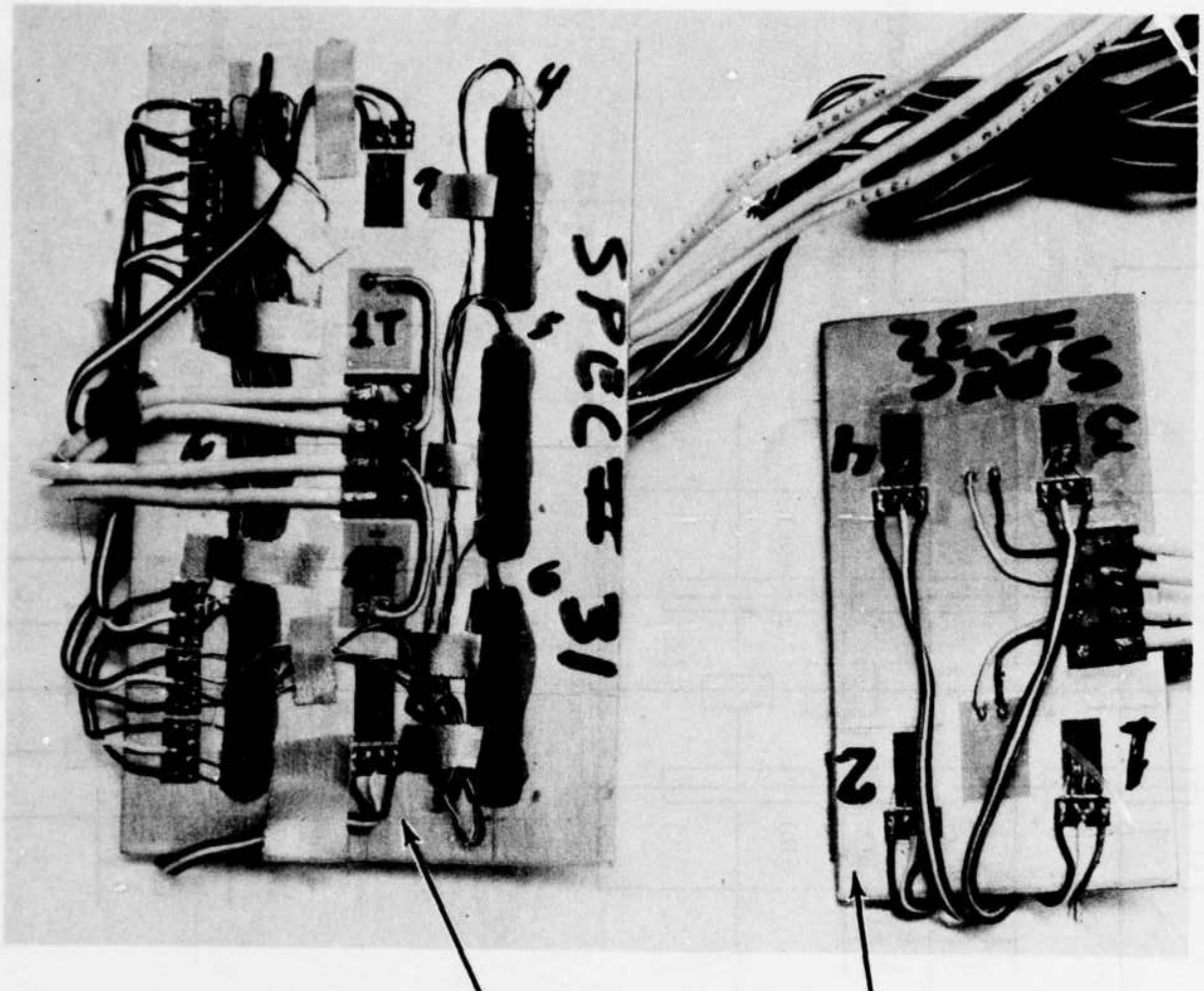


Figure 32 Temperature Induced Cycle Specimens (#31 and #32)

TABLE 16 INDUCED TEMP CYCLE DATA COLLECTION SCHEDULE

Read No.	Applied Temp Cycles	Data Required: Sensor Response	Data Required: Induced Strain Cycle
0	0	X	X
1	5	X	X
2	10	X	X
3	15	X	
4	20	X	
5	25	X	X
6	30	X	
7	40	X	
8	50	X	X

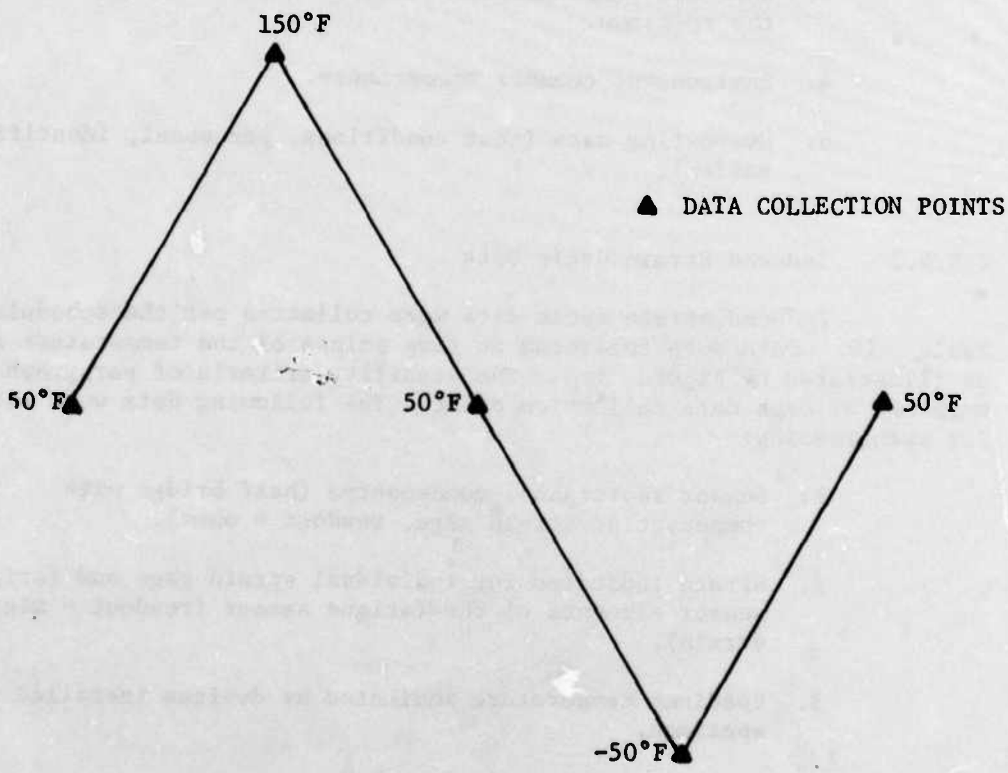


Figure 33 Temp Induced Strain Cycle Data Collection Points

2.5.6 Test Data Collected

Two types of test data were collected:

a) Sensor response data.

b) Induced (apparent) strain cycle.

2.5.6.1 Sensor Response Data

These data were collected per the schedule of Table 16 with additional readings taken as deemed appropriate by test personnel. All sensor response data were collected at 50°F ±2°F. The stability criteria of paragraph 2.5.5 were met at 50°F before sensor data were collected. The following data were recorded for each reading:

1. Sensor resistance, compensated (half bridge with compensating strain gage, readout = ohms).

2. Resistance of individual strain gage and fatigue sensor elements (readout = ohms).

3. Specimen temperature indicated by devices installed on the specimen.

4. Environment chamber temperature.

5. Supporting data (test conditions, personnel, identification).

2.5.6.2 Induced Strain Cycle Data

Induced strain cycle data were collected per the schedule of Table 16. Data were collected at five points of the temperature cycle as illustrated by Figure 33. The stability criteria of paragraph 2.5.5 were met at each data collection point. The following data were required for each reading:

1. Sensor resistance, compensated (half bridge with compensating strain gage, readout = ohms).

2. Strain indicated for individual strain gage and fatigue sensor elements of the fatigue sensor (readout = microstrain).

3. Specimen temperature indicated by devices installed on specimen.

4. Environment chamber temperature.

5. Supporting data (test conditions, personnel, identification).

2.5.7 Data Collection Schedule

Sensor response data and induced strain cycle data were collected per Table 16.

2.5.8 Test Operation

The two specimens were placed in the environment chamber with no mechanical restraint (similar to ambient temperature specimen in Figure 25). Temperature cycles were applied using the mechanical cam operation mode of the environment chamber. Test data were collected per Table 16.

The temperature time history of the environment chamber was monitored by a 24 hour circular chart recorder (see Figure 26). Temperature cycle application was monitored to assure that the stability and transition rate criteria of paragraph 2.5.5 were met.

2.6 CREEP TEST

2.6.1 Introduction

Specimen #29 was subjected to a static load of 1000 $\mu\varepsilon$ for a 24 hour time period at room temperature (this test was accomplished after cyclic temperature tests were complete, section 2.2). Specimen fatigue sensors and strain gages were monitored periodically during this time period. The static load was removed after 24 hours and fatigue sensors and strain gages were monitored an additional 24 hours.

2.6.2 Test Setup

Specimen #29 was installed in the MTS machine hanging from the upper loading fixture as shown by Figure 34. A weight pan was installed on the lower end of the specimen (Figure 35). The weight pan was loaded with lead weights to provide the target static strain (1000 $\mu\varepsilon$).

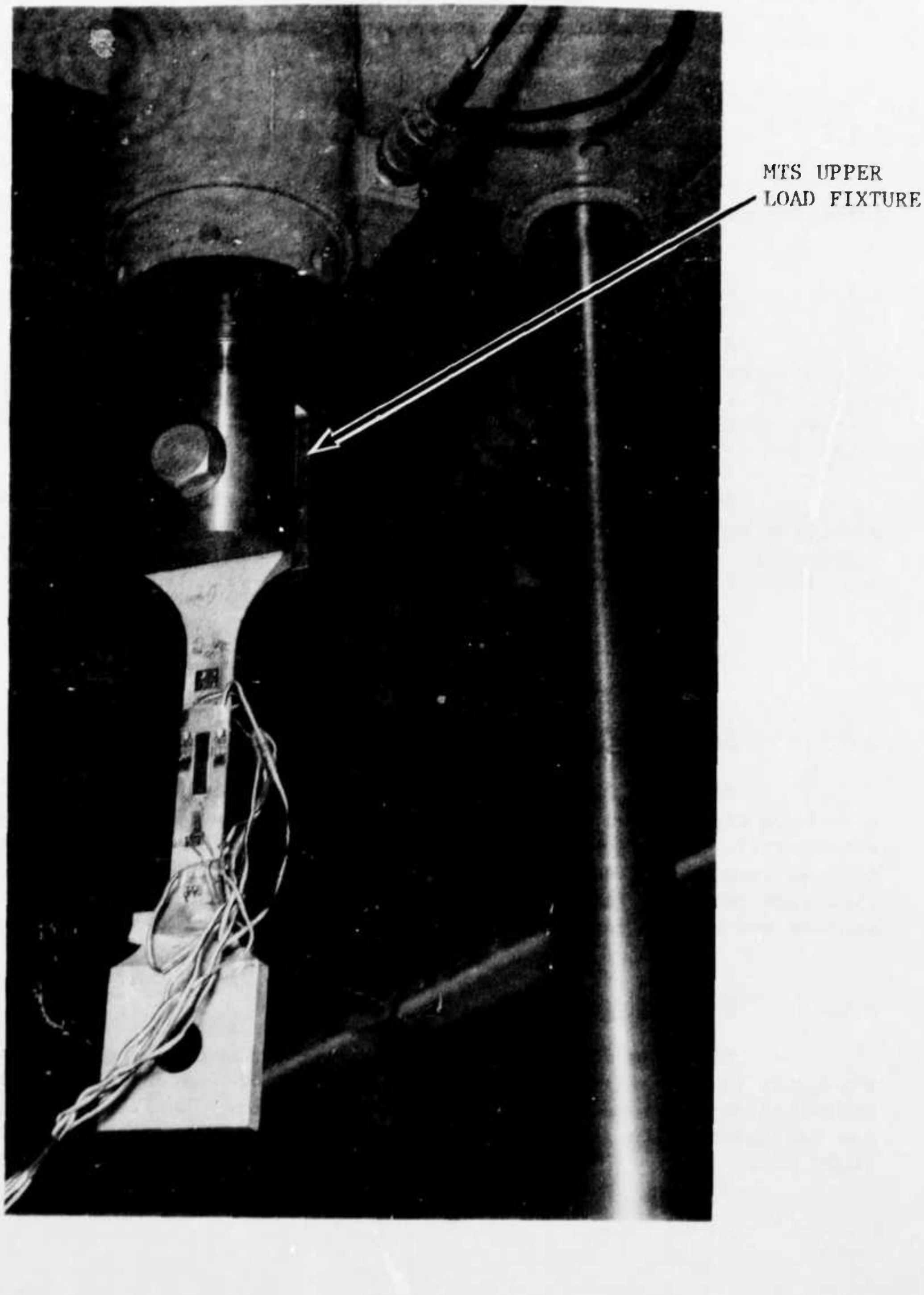


Figure 34 Creep Test in MTS Machine

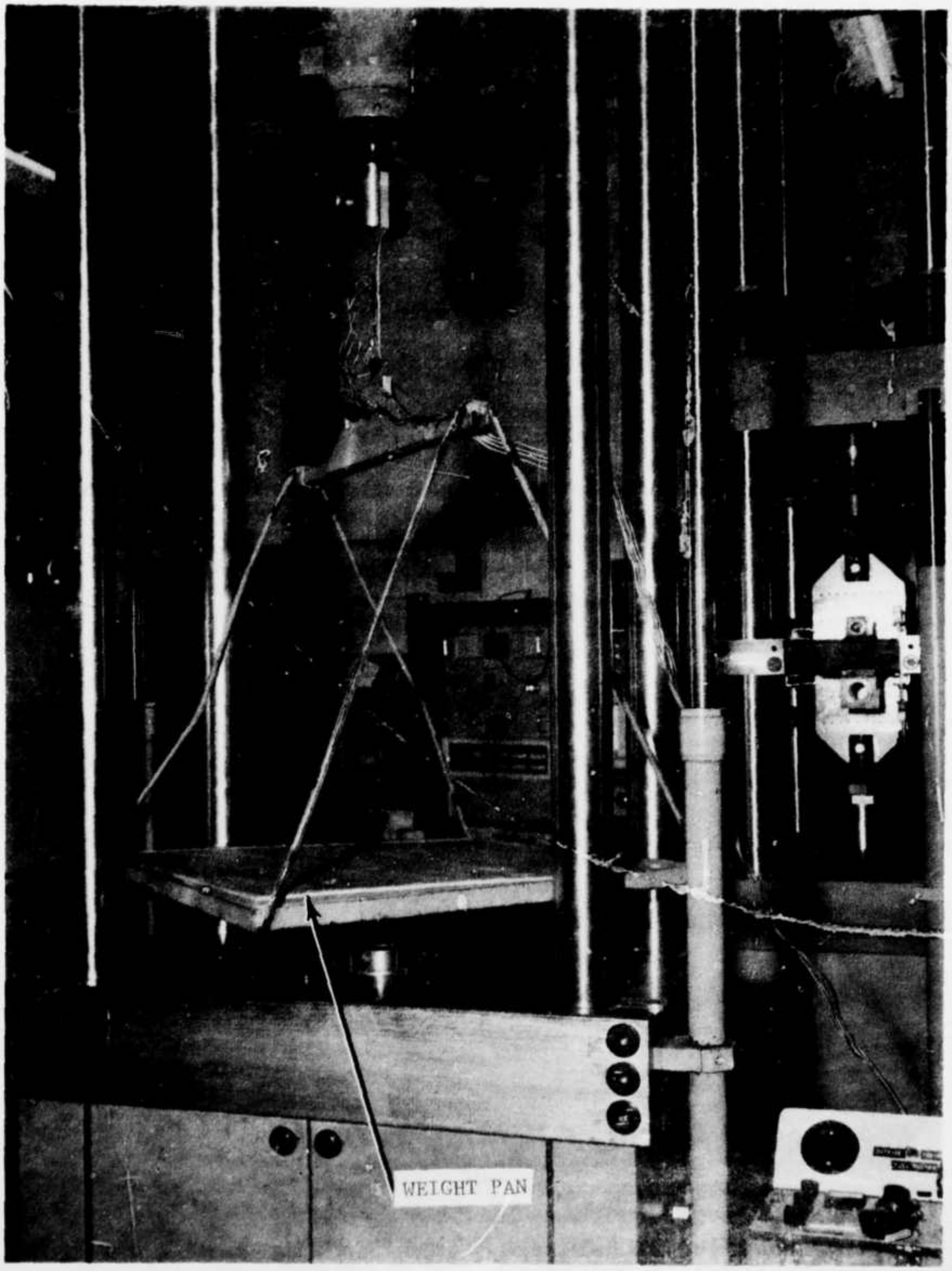


Figure 35 Creep Test, Weight Pan Installed

2.6.3 Data Collection System

The data collection system described for the cycle temperature tests was used for this test (see 2.2.4).

2.6.4 Test Operation

The following procedure was followed:

a) Zero readings were taken for fatigue sensors and strain gages in the unloaded condition.

b) A 1000 lb static load was applied.

c) Fatigue sensors and strain gages were read per the schedule of Table 17 with the static load applied.

d) The static load was removed after 24 hours application.

e) Fatigue sensors and strain gages were read per the schedule of Table 17 with the static load removed.

TABLE 17 CREEP TEST DATA COLLECTION SCHEDULE

READING NO	TIME (HOURS)	LOAD CONDITION
0	0	1000# LOAD APPLIED
1	0.25	
2	0.50	
3	0.75	
4	1.00	
5	1.50	
6	2.00	
7	3.00	
8	4.00	
9	5.00	
10	6.00	
11	7.00	
12	8.00	
13	24.00	
14	24.00	1000# LOAD REMOVED
15	24.25	
16	24.50	
17	24.75	
18	25.00	
19	25.50	
20	26.00	
21	27.00	
22	28.00	
23	29.00	
24	30.00	
25	31.00	
26	32.00	
27	48.00	

SECTION III

STRAIN CYCLE RESPONSE

3.1 INTRODUCTION

Basic fatigue sensor response to alternating strain is developed using data from six constant amplitude specimens cycled about zero mean strain (fully reversed cycles). These same data are used to evaluate fatigue sensor repeatability and data scatter. In addition, the failure mode of fatigue sensors subjected to constant amplitude cycling is presented.

3.2 DATA ANALYSES

3.2.1 Data Parameters

The data parameters required for analysis of fatigue sensor response to strain cycles are:

a) Resistance change (ΔR)

b) Number of applied cycles

c) Alternating strain

These data parameters were derived for constant amplitude specimens #1 thru #5 and #33 from raw test data (a sample of raw test data is presented by Appendix F). The calculated resistance change and number of applied cycles, for the six zero mean specimens, are presented by Tables 22 thru 27 ; these data are plotted in Figures 39 thru 44 .

The fatigue sensor alternating strain is calculated from an average of data collected during static load cycles of each specimen (see paragraph 2.1.6.2). A sample of the load cycle calculations for specimen #6 are presented by Appendix F; the alternating strain values indicated by the FM fatigue sensor strain gage element were averaged to provide an alternating strain for data analysis.

The average alternating strain was calculated using a three step iteration to eliminate data exceeding a ±2% deviation from the average (tolerance set for high confidence in resulting average). Initially, all alternating strain values for a particular sensor (maximum of 9) were averaged (data for sensors in process of failure not included). Data which exceeded ±50% of the average were eliminated and a new average was calculated. This process was repeated for tolerances of ±10% and ±2%. The final average alternating strains are presented by Table 28 (table includes all constant amplitude specimens). The alternating strain data were found to be consistent;

over 80% of the data were within ±2% of the calculated average. (Note: Average mean strain data for specimens #6 thru #23 are calculated using the same process as outlined for average alternating strain and are included in Table 28 , see Section IV).

3.2.2 Data Cross Plot

A cross plot of test data parameters was used to develop fatigue sensor calibration response (resistance change versus applied cycles). The cross plot was utilized to display a family of applied cycles curves (constant for all specimens) with ΔR plotted versus average alternating strain. Figure 36 shows the cross plotted data for the six zero mean strain specimens (thirty-five fatigue sensors operating at twenty levels of alternating strain). Note: Only nine of thirty-three curves plotted are shown by Figure 36 for clarity.

3.2.3 Curve Fit

A least squares curve fit of cross plotted data was accomplished as a final step in developing calibration response. Figure 36 shows the final curve fit of plotted test data. A computer program was developed to group test data and apply the least squares curve fit technique; the program calculated a second order equation which best fit the grouping of data points and calculated the total deviation of data points from that equation. For the majority of curves, several groupings of points and equations were required to cover the total curve, i.e. one second order equation would not fit the entire curve. The computer program also produced a table of plotting points based on the equation(s) generated by the least squares curve fit. A value of ΔR was given for each of the selected levels of alternating strain from 1000 to 6000 $\mu\epsilon$. A sample printout of the least squares computer program is presented by Appendix D (curve fit of 100 cycle cross plot data, Figure 36.).

3.2.4 Calibration Data

The final curve fit plotting points (see Table D-1) from the cross plot were used to form Table 18 which presents basic fatigue sensor response data. These data were plotted to form "Plot C" calibration curves shown in Figure 37 . This graph of ΔR versus applied cycles for constant levels of alternating strain was accepted as standard fatigue sensor response for all additional analyses of this program.

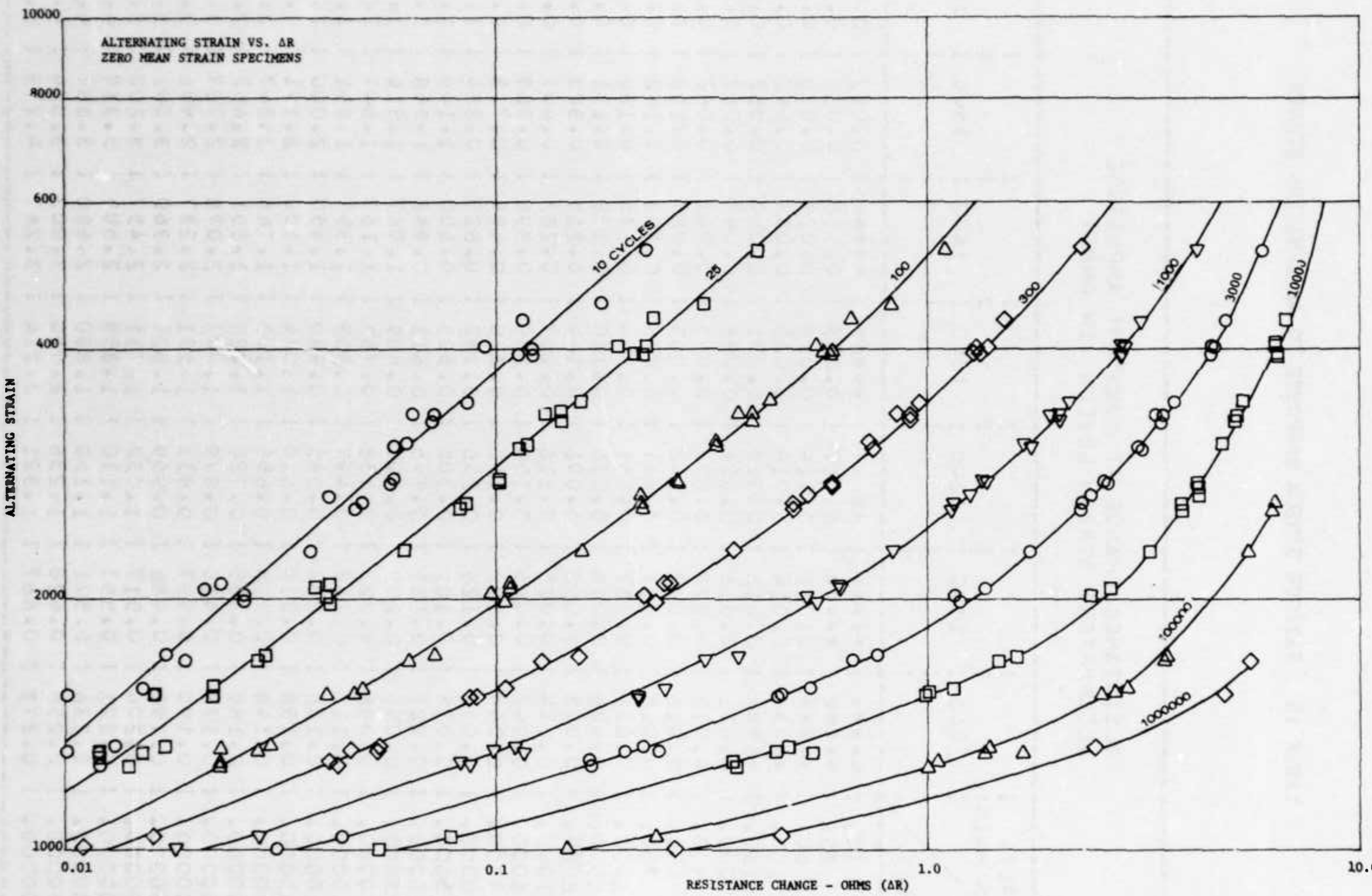


Figure 36 Curve Fitting Cross Plot Of Zero Mean Strain Test Data

TABLE 18 FATIGUE SENSOR RESPONSE TO ALTERNATING STRAIN

RESISTANCE CHANGE AT CONSTANT AMPLITUDE ALTERNATING STRAIN LEVELS (IN OHMS)

CYCLES \ ALT. STRAIN	1000	1100	1200	1300	1400	1500	1600
10.	*****	*****	*****	*****	*****	0.012	0.014
25.	*****	*****	0.011	0.013	0.016	0.020	0.023
50.	*****	0.011	0.014	0.018	0.023	0.028	0.033
100.	*****	0.014	0.019	0.025	0.033	0.042	0.051
150.	*****	0.016	0.022	0.031	0.040	0.052	0.065
200.	0.011	0.018	0.026	0.036	0.047	0.063	0.079
300.	0.013	0.022	0.032	0.045	0.062	0.082	0.107
500.	0.016	0.027	0.042	0.063	0.087	0.118	0.154
700.	0.018	0.031	0.051	0.076	0.108	0.148	0.194
1000.	0.021	0.037	0.061	0.094	0.135	0.188	0.250
1500.	0.025	0.045	0.076	0.120	0.178	0.251	0.337
2000.	0.028	0.052	0.091	0.144	0.215	0.303	0.409
3000.	0.034	0.065	0.116	0.187	0.283	0.403	0.545
5000.	0.042	0.085	0.156	0.259	0.396	0.569	0.780
7000.	0.049	0.102	0.190	0.320	0.495	0.713	0.969
10000.	0.059	0.126	0.236	0.398	0.620	0.884	1.201
15000.	0.073	0.161	0.305	0.505	0.800	1.144	1.556
20000.	0.082	0.181	0.355	0.613	0.952	1.358	1.761
25000.	0.091	0.203	0.400	0.689	1.067	1.516	1.931
30000.	0.098	0.223	0.438	0.753	1.163	1.647	2.100
40000.	0.112	0.253	0.497	0.853	1.357	1.851	2.301
50000.	0.126	0.282	0.545	0.940	1.450	2.000	2.446
65000.	0.129	0.315	0.610	1.034	1.600	2.191	2.651
80000.	0.143	0.338	0.655	1.103	1.748	2.347	2.868
100000.	0.160	0.365	0.720	1.222	1.851	2.452	2.971
150000.	0.178	0.416	0.829	1.402	2.078	2.767	3.271
200000.	0.190	0.457	0.912	1.531	2.237	2.956	3.497
250000.	0.198	0.486	0.969	1.621	2.360	3.081	3.775
300000.	0.204	0.517	1.032	1.711	2.457	3.200	3.820
400000.	0.221	0.557	1.110	1.839	2.505	3.319	4.037
500000.	0.236	0.571	1.150	1.880	2.680	3.387	4.271
750000.	0.258	0.628	1.236	2.060	3.002	3.924	4.688
1000000.	0.273	0.667	1.321	2.214	3.247	4.273	5.140

TABLE 18 FATIGUE SENSOR RESPONSE TO ALTERNATING STRAIN (CONT.)

RESISTANCE CHANGE AT CONSTANT AMPLITUDE ALTERNATING STRAIN LEVELS (IN OHMS)

ALT. STRAIN / CYCLES	1700	1800	1900	2000	2100	2200	2400
10.	0.016	0.019	0.022	0.025	0.028	0.031	0.037
25.	0.027	0.032	0.036	0.041	0.047	0.053	0.065
50.	0.040	0.048	0.055	0.063	0.072	0.082	0.104
100.	0.063	0.075	0.088	0.102	0.118	0.135	0.173
150.	0.081	0.098	0.118	0.138	0.160	0.185	0.238
200.	0.102	0.122	0.145	0.170	0.197	0.227	0.291
300.	0.135	0.165	0.199	0.235	0.273	0.302	0.401
500.	0.194	0.240	0.289	0.342	0.397	0.456	0.576
700.	0.246	0.305	0.370	0.439	0.512	0.588	0.746
1000.	0.315	0.406	0.480	0.571	0.647	0.748	0.948
1500.	0.435	0.544	0.660	0.781	0.905	1.028	1.274
2000.	0.529	0.687	0.794	0.948	1.108	1.272	1.567
3000.	0.707	0.885	1.073	1.267	1.461	1.638	1.941
5000.	1.020	1.254	1.505	1.753	1.988	2.204	2.557
7000.	1.253	1.553	1.775	2.090	2.349	2.593	3.005
10000.	1.547	1.913	2.163	2.470	2.793	3.015	3.454
15000.	1.894	2.251	2.526	2.907	3.201	3.410	3.827
20000.	2.182	2.510	2.851	3.229	3.560	3.793	4.320
25000.	2.301	2.671	3.039	3.399	3.743	4.057	4.515
30000.	2.541	2.907	3.267	3.617	3.952	4.200	4.746
40000.	2.704	3.151	3.500	3.800	4.200	4.400	4.908
50000.	2.962	3.304	3.640	3.968	4.285	4.590	5.156
65000.	3.130	3.495	3.852	4.198	4.530	4.846	5.424
80000.	3.256	3.701	4.013	4.359	4.684	4.996	5.577
100000.	3.382	3.901	4.185	4.567	4.930	5.273	5.888
150000.	3.784	4.272	4.645	5.000	5.335	5.648	6.209
200000.	4.030	4.498	4.892	5.268	5.626	5.964	6.575
250000.	4.284	4.671	5.200	5.435	5.808	6.175	6.887
300000.	4.531	5.054	5.526	5.939	6.288	6.572	6.947
400000.	4.794	5.495	6.112	6.623	*****	*****	*****
500000.	5.191	6.112	*****	*****	*****	*****	*****
750000.	5.750	*****	*****	*****	*****	*****	*****
1000000.	6.200	*****	*****	*****	*****	*****	*****

TABLE 18 FATIGUE SENSOR RESPONSE TO ALTERNATING STRAIN (CONT.)

RESISTANCE CHANGE AT CONSTANT AMPLITUDE ALTERNATING STRAIN LEVELS (IN OHMS)

ALT. STRAIN / CYCLES	2600	2800	3000	3200	3400	3600	3800
10.	0.044	0.052	0.060	0.069	0.079	0.090	0.101
25.	0.079	0.094	0.110	0.128	0.148	0.169	0.191
50.	0.129	0.155	0.184	0.215	0.247	0.281	0.317
100.	0.214	0.260	0.309	0.362	0.417	0.476	0.537
150.	0.297	0.361	0.429	0.501	0.575	0.651	0.729
200.	0.362	0.439	0.522	0.606	0.694	0.786	0.883
300.	0.503	0.612	0.727	0.846	0.966	1.067	1.198
500.	0.711	0.860	1.019	1.184	1.354	1.527	1.703
700.	0.905	1.087	1.282	1.484	1.691	1.900	2.108
1000.	1.162	1.389	1.624	1.865	2.108	2.350	2.591
1500.	1.554	1.831	2.090	2.362	2.634	2.904	3.170
2000.	1.856	2.152	2.450	2.749	3.045	3.336	3.620
3000.	2.293	2.646	2.996	3.338	3.668	3.959	4.253
5000.	3.033	3.392	3.742	4.083	4.411	4.726	5.027
7000.	3.478	3.896	4.248	4.558	4.887	5.202	5.503
10000.	3.883	4.298	4.697	5.076	5.436	5.775	6.093
15000.	4.330	4.812	5.270	5.701	6.102	6.473	6.814
20000.	4.712	5.194	5.644	6.059	6.438	6.781	*****
25000.	4.967	5.413	5.851	6.282	6.704	*****	*****
30000.	5.181	5.602	6.006	6.394	6.767	*****	*****
40000.	5.458	5.957	6.403	6.794	*****	*****	*****
50000.	5.666	6.149	6.580	6.961	*****	*****	*****
65000.	5.924	6.343	6.682	*****	*****	*****	*****
80000.	6.095	6.548	*****	*****	*****	*****	*****
100000.	6.404	6.600	*****	*****	*****	*****	*****
150000.	6.677	*****	*****	*****	*****	*****	*****
200000.	*****	*****	*****	*****	*****	*****	*****
250000.	*****	*****	*****	*****	*****	*****	*****
300000.	*****	*****	*****	*****	*****	*****	*****
400000.	*****	*****	*****	*****	*****	*****	*****
500000.	*****	*****	*****	*****	*****	*****	*****
750000.	*****	*****	*****	*****	*****	*****	*****
1000000.	*****	*****	*****	*****	*****	*****	*****

TABLE 18 FATIGUE SENSOR RESPONSE TO ALTERNATING STRAIN (CONCLUDED)

RESISTANCE CHANGE AT CONSTANT AMPLITUDE ALTERNATING STRAIN LEVELS (IN OHMS)

CYCLES \ ALT. STRAIN	4000	4300	4600	4900	5200	5500	6000
10.	0.113	0.133	0.155	0.178	0.203	0.230	0.279
25.	0.214	0.252	0.293	0.337	0.383	0.432	0.520
50.	0.355	0.415	0.478	0.543	0.610	0.680	0.799
100.	0.601	0.699	0.800	0.903	1.008	1.114	1.291
150.	0.808	0.937	1.070	1.206	1.343	1.480	1.709
200.	0.999	1.145	1.313	1.489	1.671	1.801	2.088
300.	1.331	1.534	1.740	1.946	2.150	2.352	2.678
500.	1.879	2.141	2.398	2.648	2.887	3.114	3.464
700.	2.316	2.621	2.916	3.197	3.462	3.710	4.080
1000.	2.826	3.169	3.493	3.798	4.079	4.337	4.713
1500.	3.432	3.812	4.173	4.515	4.835	5.133	5.579
2000.	3.895	4.290	4.661	5.005	5.323	5.613	6.036
3000.	4.534	4.929	5.292	5.623	5.922	6.189	6.569
5000.	5.313	5.714	6.083	6.418	6.722	6.995	*****
7000.	5.790	6.194	6.566	6.908	*****	*****	*****
10000.	6.390	6.797	*****	*****	*****	*****	*****
15000.	*****	*****	*****	*****	*****	*****	*****
20000.	*****	*****	*****	*****	*****	*****	*****
25000.	*****	*****	*****	*****	*****	*****	*****
30000.	*****	*****	*****	*****	*****	*****	*****
40000.	*****	*****	*****	*****	*****	*****	*****
50000.	*****	*****	*****	*****	*****	*****	*****
65000.	*****	*****	*****	*****	*****	*****	*****
80000.	*****	*****	*****	*****	*****	*****	*****
100000.	*****	*****	*****	*****	*****	*****	*****
150000.	*****	*****	*****	*****	*****	*****	*****
200000.	*****	*****	*****	*****	*****	*****	*****
250000.	*****	*****	*****	*****	*****	*****	*****
300000.	*****	*****	*****	*****	*****	*****	*****
400000.	*****	*****	*****	*****	*****	*****	*****
500000.	*****	*****	*****	*****	*****	*****	*****
750000.	*****	*****	*****	*****	*****	*****	*****
1000000.	*****	*****	*****	*****	*****	*****	*****

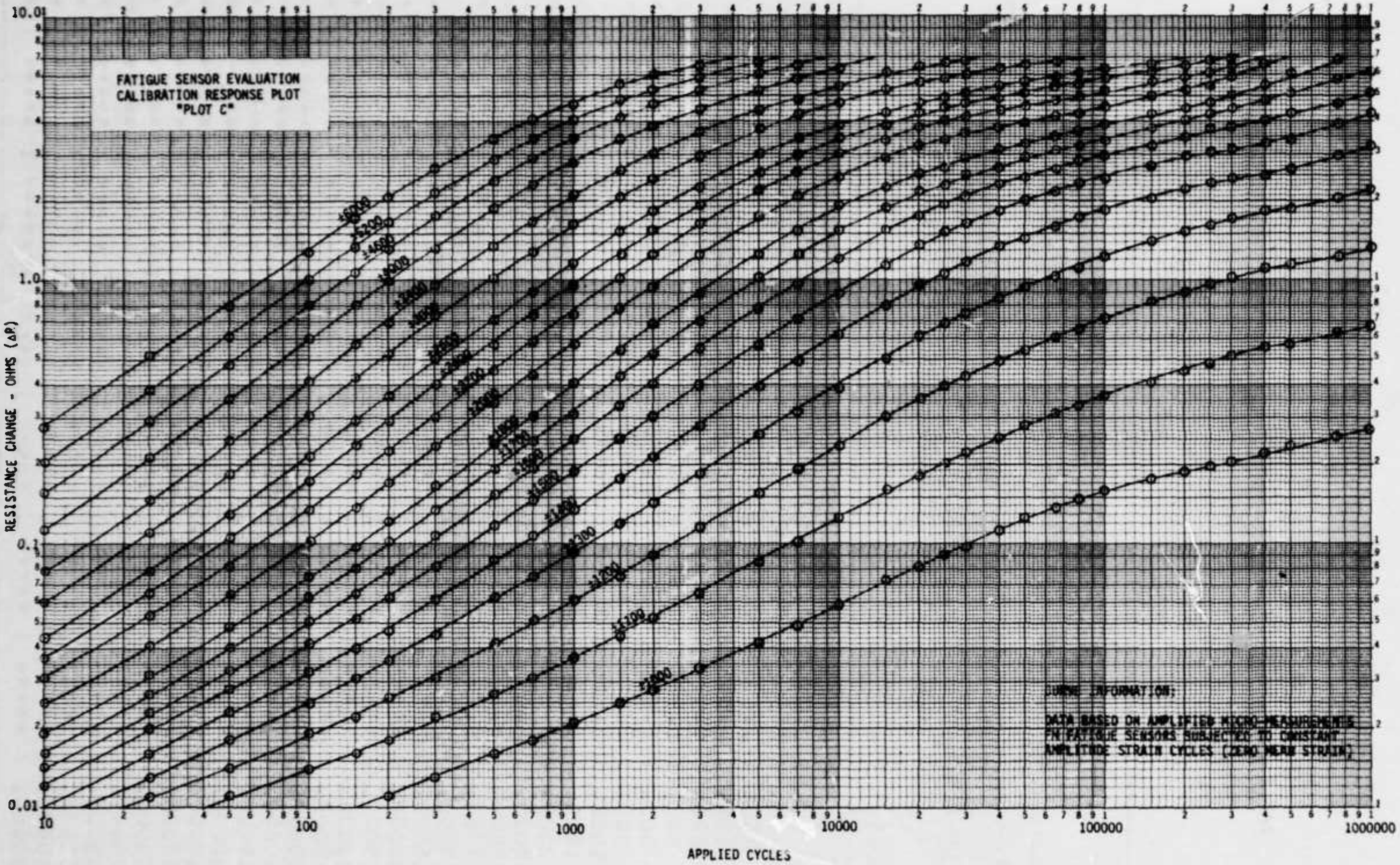


Figure 37 Calibration Response Plot "C"

Plot "C" fatigue sensor calibration response was compared to Plot "A" (derived from Micro-Measurements' data) shown by Figure 45. Plot "C" response was found to be slightly higher than that indicated by manufacturer's data. It is theorized the higher response may be produced by a difference in test methods; Micro-Measurements used a bending beam specimen to generate calibration curve data versus the axial specimen of this test series.

3.3 DATA REPEATABILITY AND SCATTER

Data scatter and repeatability of fatigue sensors are graphically represented by the data cross-plot, Figure 36. The raw data, taken from thirty-five fatigue sensors on six individual specimens and superimposed on the analytically fitted curves, illustrates the excellent grouping and minimum scatter of fatigue sensor data. Table 19 gives representative scatter data at selected points throughout the life of the sensors. The percentages in the table are based on the deviation of the raw data (ΔR) from the fitted curves. It should be noted the maximum scatter points are all from sensors operating at the lower alternating strains. Low alternating strains are more susceptible to test variations and scatter because of the inherent "threshold effect" of fatigue sensor response and the sensitivity of low alternatings to mean strain variations (see Section IV). Also, it is noted the fatigue sensor tends to stabilize after initial cycles (up to 100) with a marked improvement in scatter after these cycles.

It is concluded from this test data the FM fatigue sensor will operate with approximately $\pm 5\%$ scatter and repeatability excepting:

a) Early sensor life (less than 100 cycles).

b) Low alternating strain (less than ± 1300 $\mu\varepsilon$).

Since neither of these responses is significant in normal fatigue sensor applications, the $\pm 5\%$ tolerance is projected for overall FM fatigue sensor performance.

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FATIGUE SENSOR EVALUATION PROGRAM LABORATORY TEST REPORT.(U)
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UNCLASSIFIED 318E-7319-047 ASD-TR-75-33 NL

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TABLE 19 TYPICAL REPEATABILITY AND SCATTER DATA

Applied Cycles	Max. Negative Scatter				Max. Positive Scatter				Average Percent Dev. All Sensors*
	Spec. No.	Sen. No.	Alt. Strain	% Dev.	Spec. No.	Sen. No.	Alt. Strain	% Dev.	
10	33	5M	1538	-25	1	5M	1544	+18	10.6
100	1	1U	1318	-13	33	6L	1720	+10	4.9
1000	33	4U	1003	-13	33	6L	1720	+17	4.5
10000	33	4U	1003	-11	1	2M	1315	+28	3.7
100000	33	4U	1003	-11	1	2M	1315	+31	5.1

NOTE: Data based on percentage deviation of raw data (ΔR) from analytically fitted curves (see Figure 36).

* Includes 35 fatigue sensors on specimens #1 thru #5 and #33.

3.4 FAILURE MODE

3.4.1 Types of Failure

The failures of the FM fatigue sensors at the end of their useful life were classified as follows:

a) Normal

b) Early Normal

c) Premature

d) Multiplier Failure

The definition of these classifications and a discussion of the characteristics of each is as follows:

a) Normal Failure - The normal mode of failure for the FM fatigue sensor was characterized by a rapid upturn of the resistance change (ΔR) versus applied cycles curve occuring at a resistance change of 6-7 ohms. Although no in depth investigation was made of this phenomenon, it is probable that it is due to fatigue failure of the metal foil of the fatigue sensor element. The relatively fast development of fatigue cracks in the gage element would account for the rapid increase in resistance of the sensor element. In virtually every case, the strain gage element of the FM sensor continued to function for some period of time after failure of the fatigue sensor element.

b) Early Normal Failure - A plot of the point of failure of all gages, which were suspected of failing before the end of normal life, was superimposed on "Plot C". Examples of the points selected would be a sensor with a 2.5 multiplier failing before the other 2.5 multiplier sensors on a given specimen, or the sensor with a 3.0 multiplier failing before the one with a 3.5 multiplier (sensor 4U on specimen #3 is an early normal failure, see Figure 42). These data gave the grouping of points shown in Figure 38 was drawn through these points. All sensors which continued to function to this line or beyond were classified in this report as having normal life. All sensors whch did not reach this normal life line but otherwise showed the normal failure characteristics as outlined in the paragraph a) above were classified as early normal failures.

c) Premature Failure - Premature failures were classified as those occurring below the normal life line (Figure 38) and which did not show the characteristic rapid upturn of the ΔR versus cycles curve (sensor 5M on specimen #5 is a premature failure, see Figure 44). These sudden, no warning failures were the result of failure of either the fatigue sensor element or strain gage element (or both). It is possible that some failures classified as premature, might be reclassified as early normal if data had been taken at more frequent intervals. Sensors which were found to be defective on installation were classified as premature failures.

d) Multiplier Failure - Sensors classified as multiplier failures were those with inconsistent strain multiplication performance below the normal life line. It is probable that virtually all multiplier failures were the result of bond failure, either internal or between sensor and specimen. Characteristics of this type failure ranged from a gradual deterioration of multiplier performance, to completely erratic behavior, depending on the location and degree of bond failure.

3.4.2 Strain Gradient

The transverse strain gradient across the FM multiplier was considered as a possible variable in the failure mode analysis. Although the test specimen was designed to minimize transverse gradients, some gradients were present due to small material irregularities and loading fixture tolerances. Strain gradient for purposes of this discussion is defined as the difference in specimen strain, in microstrain, as measured by the two strain gages adjacent to each fatigue sensor. The centerline distance between these gages was approximately 0.75 inch and the width of the fatigue sensor mounting foot was 0.188 inch; therefore, the actual strain gradient across the sensor was about one-fourth of the strain gage measured value.

The average strain gradient for all sensors was slightly less than 20 microstrain, measured at maximum load during the 100 cycle load cycle. This is less than 1% of the maximum applied specimen strain of 2500 microstrain. There was no significant difference in the average strain gradient across those sensors classified as failing below normal sensor life, and the average gradient across the remainder of the sensors.

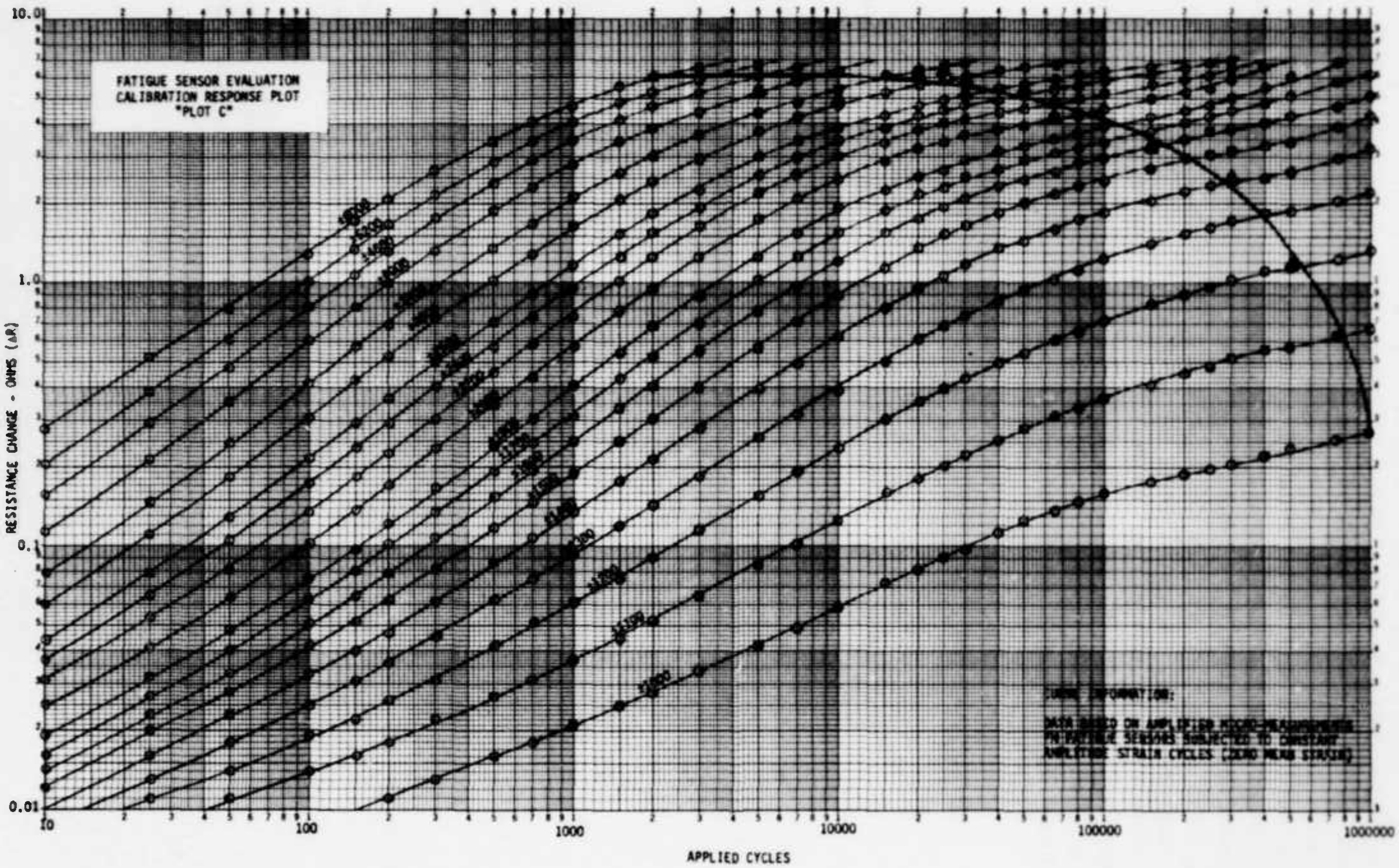

Figure 38 Normal Sensor Life Expectancy

3.4.3 Failure Mode Summary

Table 20 presents failure mode data for all sensors (constant amplitude test series) which failed in other than the normal mode. Table 21 summarizes the failure mode of all constant amplitude sensors tested (144 sensors total). The 15% rate of premature and multiplier failures was considered high and is an area of recommended improvement for the FM fatigue sensor. While the overall failure rate of approximately 20% may seem excessive, it should be remembered that many of these "failed" gages did last long enough to supply much good information. However, in view of this failure rate, it would seem advisable to have a redundancy in fatigue sensor instrumentation; in multiple gage installations, instrumenting both right and left sides, etc. In general, sensors with premature failures would function normally up to the point of failure; false indications were not produced by premature failures.

3.5 SUMMARY AND CONCLUSION

a) Basic response of FM fatigue sensors to alternating strain was developed using six constant amplitude specimens (twenty levels of alternating strain from ±1000 to ±5250 $\mu\varepsilon$).

b) The FM fatigue sensor appears to be a useful tool with repeatable and predictable response to strain cycles.

c) The scatter of FM sensor response was approximately ±5%.

d) The fatigue sensor calibration response derived from this test series compares well with manufacturer's data but was slightly higher.

e) The normal fatigue sensor failure mode was a rapid upturn of resistance change (ΔR) versus applied cycles occurring at a resistance change of 6-7 ohms.

f) A 15% failure rate (premature sensor and multiplier failures) occurred for the constant amplitude test series of 144 sensors.

g) Fatigue sensors with premature failures would function normally up to the point of failure; false indications were not produced by premature failures.

TABLE 20 ABNORMAL FAILURE MODE SUMMARY

Spec	Sens	Resistance At Start Of Failure	Cycles At Start Of Failure	Cycles At Final Failure	Target Alt. Strain	Strain Gradient @ 100CK*	Type Of Failure**
1	3L	0.05	10	--	1300	10	Mult.
	4U	0.35	300000	--	1000	8	Mult.
2	1U	0.86	1500	--	1950	33	Prem.
	2M	3.80	30000	--	1950	37	Prem.
3	4U	3.50	20000	80000	2000	65	Early Norm.
4	4U	3.60	7000	15000	2500	51	Early Norm.
5	5M	0.82	100	--	4500	8	Prem.
7	1U	3.80	30000	--	1950	5	Prem.
	6L	0.36	150	--	2625	13	Prem.
8	1U	3.20	5000	7000	2600	1	Early Norm.
	6L	2.30	1000	--	3500	18	Prem.
9	1U	--	10	--	3250	21	Prem.
	5M	0.55	100	--	3750	26	Prem.
	6L	3.30	1000	--	4375	18	Prem.
10	1U	3.80	2000	7000	3900	21	Early Norm.
	2M	5.50	10000	--	3900	33	Mult.
	4U	--	--	--	3000	59	Mult.
	5M	--	--	--	4500	48	Mult.
	6L	--	--	--	5250	27	Mult.
17	5M	5.40	5000	7000	3750	10	Early Norm.
18	5M	3.70	1000	1500	4500	51	Early Norm.
19	3L	1.25	65000	300000	2600	1	Early Norm.
22	2M	2.00	1000	1500	3250	3	Early Norm.
	3L	3.10	2000	--	3250	2	Prem.
	5M	3.80	2000	--	3750	3	Prem.
	6L	0.25	25	--	4375	0	Prem.
23	2M	2.40	700	7000	3900	20	Early Norm.
	3L	0.98	200	--	3900	0	Prem.
	5M	--	--	--	4500	30	Prem.
	6L	3.00	500	--	5250	23	Prem.
33	3L	1.10	500000	1000000	1300	15	Early Norm.

* Maximum load level (transverse gradient across sensor).
** Paragraph 3.4.1

TABLE 21 FAILURE MODE SUMMARY

Type Of Failure	No. Of Each Type	Percent Of Total
Normal	113	78.5
Early Normal	10	7.0
Premature	15	10.5
Multiplier	6	4.0
	144	100.0

3.6 STRAIN CYCLE RESPONSE SUPPORTING DATA

TABLE 22 SPECIMEN #1 RESISTANCE CHANGE DATA

SPECIMEN NO. = 1

ALT STRAIN = 500 MEAN STRAIN = 0 ZERO TEMP = 79.2

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	0.000	0.252	0.629*	1.084*	-0.533	-0.495

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	78.1	0.010	0.012	0.019	-0.007	0.016	0.019
2.	25.	78.1	0.012	0.015	0.021	-0.006	0.022	0.028
3.	50.	78.1	0.016	0.019	0.027	-0.003	0.031	0.040
4.	100.	78.1	0.023	0.028	0.034	-0.000	0.047	0.063
5.	150.	73.9	0.034	0.039	0.038	0.007	0.056	0.077
6.	200.	73.9	0.039	0.045	0.045	0.008	0.068	0.094
7.	300.	73.9	0.049	0.056	0.054	0.011	0.090	0.127
8.	500.	73.9	0.064	0.076	0.072	0.014	0.129	0.182
9.	700.	73.9	0.079	0.093	0.089	0.019	0.162	0.233
10.	1000.	74.6	0.102	0.120	0.113	0.024	0.213	0.306
11.	1500.	75.2	0.128	0.153	0.142	0.027	0.278	0.404
12.	2000.	75.2	0.152	0.183	0.172	0.032	0.342	0.499
13.	3000.	75.2	0.200	0.242	0.220	0.040	0.457	0.669
14.	5000.	76.2	0.282	0.345	0.301	0.051	0.651	0.944
15.	7000.	76.2	0.354	0.433	0.374	0.062	0.815	1.173
16.	10000.	76.5	0.445	0.545	0.465	0.075	1.016	1.451
17.	15000.	76.5	0.571	0.696	0.587	0.097	1.283	1.809
18.	20000.	76.5	0.675	0.825	0.682	0.113	1.492	2.082
19.	25000.	76.5	0.763	0.940	0.763	0.128	1.664	2.299
20.	30000.	77.7	0.837	1.031	0.824	0.136	1.806	2.474
21.	40000.	77.7	0.958	1.174	0.934	0.158	2.023	2.735
22.	50000.	78.7	1.054	1.289	1.019	0.172	2.196	2.938
23.	65000.	78.7	1.170	1.425	1.132	0.198	2.400	3.171
24.	80000.	78.7	1.261	1.539	1.217	0.217	2.558	3.349
25.	100000.	80.0	1.358	1.661	1.316	0.237	2.718	3.525
25.	120000.	80.0	1.429	1.751	1.408	0.253	2.840	3.661
26.	150000.	77.8	1.508	1.860	1.504	0.271	2.983	3.828
27.	200000.	79.4	1.610	2.007	1.743	0.302	3.174	4.040
28.	250000.	80.2	1.695	2.110	1.920	0.325	3.327	4.210
29.	300000.	80.5	1.769	2.227	2.017	0.346	3.449	4.343
30.	400000.	81.5	1.933	2.419	2.205	0.381	3.673	4.580
31.	500000.	81.6	2.152	2.985	2.379	0.399	3.859	4.770
32.	750000.	79.1	2.464	3.437	2.671	0.437	4.293	5.173
32.	850000.	80.9	2.620	3.616	2.810	0.443	4.511	5.396
33.	1000000.	80.8	2.684	3.893	2.984	0.461	4.848	5.666

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

* **Delta R based on fatigue sensor only**

TABLE 23 SPECIMEN #2 RESISTANCE CHANGE DATA

SPECIMEN NO. = 2

ALT STRAIN = 750 MEAN STRAIN = 0 ZERO TEMP = 74.0

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.041	0.233	-0.141	-0.740	-0.379	-0.100

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	11.	74.5	0.023	0.026	0.026	0.015	0.037	0.047
2.	25.	74.5	0.042	0.040	0.041	0.022	0.061	0.082
3.	50.	74.5	0.065	0.062	0.065	0.031	0.097	0.134
4.	100.	74.5	0.107	0.098	0.105	0.049	0.159	0.220
5.	150.	74.8	0.146	0.133	0.142	0.063	0.215	0.298
6.	200.	74.8	0.181	0.165	0.176	0.081	0.266	0.369
7.	300.	74.8	0.244	0.218	0.234	0.105	0.355	0.494
8.	500.	74.8	0.358	0.318	0.336	0.151	0.515	0.710
9.	700.	74.8	0.469	0.406	0.429	0.191	0.655	0.900
10.	1000.	74.8	0.627	0.526	0.552	0.247	0.837	1.146
11.	1500.	74.8	0.865	0.708	0.741	0.330	1.107	1.499
12.	2000.	74.8	1.417	0.870	0.907	0.404	1.337	1.793
13.	3000.	75.0	1.943	1.154	1.199	0.538	1.726	2.269
14.	5000.	75.0	2.423	1.616	1.659	0.757	2.296	2.933
15.	7000.	75.0	2.694	1.971	2.010	0.937	2.700	3.375
16.	10000.	75.3	3.343	2.386	2.407	1.157	3.136	3.834
17.	15000.	75.6	4.472	2.903	2.866	1.444	3.618	4.323
18.	20000.	75.6	4.462	3.310	3.186	1.668	3.940	4.646
19.	25000.	75.6	4.998	3.607	3.427	1.834	4.179	4.890
20.	30000.	76.1	0.000	3.853	3.624	1.980	4.371	5.082
21.	40000.	76.1	0.000	0.000	3.905	2.197	4.642	5.350
22.	50000.	76.6	0.000	0.000	4.133	2.374	4.863	5.573
23.	65000.	76.6	0.000	0.000	4.375	2.575	5.094	5.799
24.	80000.	76.6	0.000	0.000	4.582	2.738	5.282	5.990
25.	100000.	77.6	0.000	0.000	4.794	2.915	5.493	6.201
26.	150000.	78.2	0.000	0.000	5.306	3.231	5.870	6.686
27.	200000.	78.9	0.000	0.000	8.589	3.496	6.177	7.128
28.	250000.	74.6	0.000	0.000	0.000	3.727	6.405	7.592
29.	300000.	76.3	0.000	0.000	0.000	4.057	6.790	8.388
30.	400000.	78.8	0.000	0.000	0.000	4.775	7.419	0.000
31.	500000.	80.1	0.000	0.000	0.000	5.651	8.101	0.000
32.	560000.	80.0	0.000	0.000	0.000	0.000	8.602	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE 24 SPECIMEN #3 RESISTANCE CHANGE DATA

SPECIMEN NO. = 3

ALT STRAIN = 1000 MEAN STRAIN = 0 ZERO TEMP = 74.0

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.698	-0.883	-0.574	-0.631	-0.274	0.140

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	74.6	0.058	0.049	0.057	0.021	0.062	0.086
2.	25.	74.6	0.101	0.085	0.100	0.038	0.118	0.157
3.	50.	74.6	0.165	0.136	0.164	0.066	0.195	0.262
4.	100.	74.7	0.266	0.220	0.267	0.108	0.327	0.431
5.	150.	75.1	0.358	0.298	0.361	0.148	0.444	0.583
6.	200.	75.1	0.440	0.376	0.445	0.184	0.545	0.718
7.	300.	75.1	0.591	0.493	0.601	0.253	0.729	0.959
8.	500.	75.1	0.853	0.713	0.866	0.374	1.052	1.373
9.	700.	75.3	1.069	0.903	1.088	0.483	1.320	1.712
10.	1000.	75.3	1.356	1.156	1.382	0.634	1.673	2.142
11.	1500.	75.3	1.764	1.521	1.801	0.858	2.166	2.720
12.	2000.	75.3	2.084	1.813	2.128	1.046	2.544	3.143
13.	3000.	75.8	2.589	2.290	2.646	1.371	3.121	3.759
14.	5000.	75.8	3.286	2.962	3.350	1.867	3.882	4.540
15.	7000.	75.8	3.757	3.423	3.817	2.240	4.370	4.987
16.	10000.	76.2	4.235	3.886	4.272	2.646	4.834	5.330
17.	15000.	76.2	4.779	4.399	4.777	3.133	5.341	5.705
18.	20000.	76.2	5.156	4.727	5.096	3.489	5.655	5.929
19.	25000.	76.2	5.481	4.981	5.351	3.788	5.910	6.108
20.	30000.	77.0	5.758	5.166	5.536	4.056	6.090	6.230
21.	40000.	77.0	6.594	5.451	5.842	4.655	6.372	6.418
22.	50000.	77.0	7.505	5.666	6.067	5.350	6.587	6.561
23.	65000.	78.8	8.604	5.897	6.347	6.772	6.827	6.729
24.	80000.	78.8	10.113	6.074	6.573	8.831	7.058	6.873
25.	100000.	78.8	0.000	6.280	6.901	0.000	7.509	7.078
25.	100000.	76.3	0.000	6.219	6.827	0.000	7.429	7.008
26.	150000.	78.7	0.000	6.696	8.533	0.000	8.520	7.749
26.	175000.	80.2	0.000	6.895	9.341	0.000	9.351	8.158
27.	200000.	82.1	0.000	7.086	11.549	0.000	10.049	8.539
28.	250000.	83.2	0.000	7.558	0.000	0.000	0.000	0.000
29.	300000.	84.8	0.000	8.064	0.000	0.000	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE 25 SPECIMEN #4 RESISTANCE CHANGE DATA

SPECIMEN NO. = 4

ALT STRAIN = 1250 MEAN STRAIN = 0 ZERO TEMP = 76.9

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.394	-0.335	-0.365	-0.762	-0.759	0.110

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	78.4	0.064	0.071	0.072	0.040	0.094	0.115
2.	25.	78.4	0.129	0.142	0.144	0.065	0.190	0.230
3.	50.	78.3	0.211	0.231	0.232	0.118	0.321	0.385
4.	100.	78.3	0.363	0.396	0.397	0.215	0.557	0.661
5.	150.	78.0	0.501	0.542	0.543	0.303	0.774	0.909
6.	200.	78.0	0.621	0.670	0.670	0.379	0.962	1.122
7.	300.	78.0	0.846	0.906	0.905	0.524	1.299	1.500
8.	500.	78.0	1.216	1.296	1.294	0.767	1.844	2.100
9.	700.	78.0	1.532	1.628	1.625	0.987	2.286	2.577
10.	1000.	78.1	1.925	2.035	2.032	1.262	2.804	3.123
11.	1500.	78.1	2.420	2.545	2.543	1.620	3.420	3.762
12.	2000.	78.1	2.828	2.961	2.965	1.937	3.894	4.241
13.	3000.	78.3	3.413	3.549	3.566	2.425	4.531	4.881
14.	5000.	78.3	4.144	4.268	4.326	3.104	5.325	5.663
15.	7000.	78.3	4.614	4.718	4.816	3.613	5.837	6.158
16.	10000.	78.0	5.113	5.172	5.328	4.277	6.420	6.707
17.	15000.	78.0	5.691	5.712	5.963	5.801	7.321	7.490
18.	20000.	78.0	6.085	6.073	6.416	0.000	0.000	8.191
18.	20000.	76.4	6.024	6.003	6.346	0.000	0.000	8.112
19.	25000.	77.2	6.393	6.415	6.844	0.000	0.000	9.136
20.	30000.	77.9	6.648	0.000	7.723	0.000	0.000	9.859
21.	40000.	78.2	7.250	0.000	8.577	0.000	0.000	0.000
22.	50000.	79.4	0.000	0.000	9.634	0.000	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE 26 SPECIMEN #5 RESISTANCE CHANGE DATA

SPECIMEN NO. = 5

ALT STRAIN = 1500 MEAN STRAIN = 0 ZERO TEMP = 75.4

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.549	-0.418	-0.122	0.606	-0.905	-0.261

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.4	0.121	0.121	0.113	0.056	0.175	0.222
2.	25.	76.4	0.218	0.221	0.209	0.112	0.302	0.403
3.	50.	76.4	0.359	0.367	0.346	0.191	0.493	0.662
4.	100.	76.0	0.598	0.614	0.578	0.327	0.826	1.093
5.	150.	76.0	0.807	0.832	0.786	0.451	0.000	1.464
6.	200.	76.0	0.993	1.025	0.969	0.561	0.000	1.776
7.	300.	76.0	1.317	1.362	1.294	0.756	0.000	2.300
8.	500.	76.0	1.855	1.919	1.834	1.094	0.000	3.090
9.	700.	76.0	2.283	2.359	2.268	1.382	0.000	3.661
10.	1000.	75.6	2.789	2.876	2.782	1.741	0.000	4.274
11.	1500.	75.6	3.419	3.508	3.420	2.213	0.000	4.975
12.	2000.	75.6	3.883	3.971	3.890	2.500	0.000	5.449
13.	3000.	75.6	4.505	4.589	4.530	3.154	0.000	6.057
14.	5000.	75.6	5.283	5.347	5.326	3.880	0.000	6.857
15.	7000.	75.6	5.761	5.807	5.812	4.356	0.000	0.000
16.	9000.	76.7	6.103	6.112	6.152	4.705	0.000	8.788
16.	10000.	76.7	6.525	6.432	6.536	5.110	0.000	0.000
17.	15000.	76.7	7.537	7.240	7.158	5.634	0.000	0.000
18.	20000.	76.7	0.000	11.251	7.694	6.002	0.000	0.000
18.	20000.	74.2	0.000	9.768	7.614	5.976	0.000	0.000
19.	25000.	75.2	0.000	0.000	8.611	6.360	0.000	0.000
20.	30000.	76.5	0.000	0.000	0.000	6.667	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE 27 SPECIMEN #33 RESISTANCE CHANGE DATA

SPECIMEN NO. = 33

ALT STRAIN = 500 MEAN STRAIN = 0 ZERO TEMP = 74.5

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.683	-0.629	-0.279	-0.988	-0.564	-0.225

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
0.	2.	73.8	0.011	0.009	0.012	0.005	0.009	0.011
1.	10.	74.3	0.013	0.009	0.012	0.004	0.010	0.017
2.	25.	74.4	0.017	0.012	0.014	0.005	0.016	0.029
3.	50.	74.4	0.023	0.016	0.013	0.006	0.026	0.045
4.	100.	74.1	0.030	0.023	0.023	0.007	0.040	0.072
5.	150.	74.3	0.038	0.028	0.029	0.009	0.055	0.095
6.	200.	74.4	0.044	0.031	0.034	0.010	0.067	0.116
7.	300.	74.4	0.054	0.041	0.043	0.011	0.086	0.155
8.	500.	74.5	0.077	0.057	0.060	0.016	0.129	0.222
9.	700.	74.4	0.092	0.069	0.071	0.018	0.164	0.287
10.	1000.	74.5	0.111	0.083	0.087	0.018	0.213	0.367
11.	1500.	74.5	0.143	0.107	0.109	0.021	0.279	0.483
12.	2000.	74.5	0.169	0.127	0.131	0.026	0.341	0.585
13.	3000.	74.2	0.220	0.165	0.168	0.031	0.453	0.772
14.	5000.	74.2	0.306	0.227	0.234	0.039	0.642	1.075
15.	7000.	74.2	0.380	0.283	0.291	0.044	0.797	1.315
16.	10000.	74.4	0.479	0.355	0.364	0.054	0.987	1.605
17.	15000.	74.4	0.614	0.452	0.469	0.064	1.229	1.956
18.	20000.	74.4	0.726	0.534	0.544	0.073	1.419	2.218
19.	25000.	74.4	0.817	0.603	0.611	0.081	1.573	2.422
20.	30000.	75.0	0.896	0.667	0.665	0.092	1.702	2.585
21.	40000.	75.0	1.015	0.761	0.759	0.101	1.902	2.839
22.	50000.	75.0	1.111	0.839	0.836	0.114	2.066	3.037
23.	65000.	75.4	1.221	0.925	0.911	0.128	2.250	3.257
23.	75000.	75.4	1.281	0.972	0.977	0.136	2.352	3.378
23.	75000.	75.2	1.272	0.966	1.007	0.132	2.325	3.337
24.	80000.	75.2	1.297	0.986	0.955	0.135	2.368	3.393
25.	100000.	75.7	1.387	1.058	1.009	0.147	2.514	3.616
26.	150000.	75.7	1.563	1.193	1.127	0.165	2.775	4.004
27.	200000.	75.8	1.683	1.287	1.233	0.178	2.956	4.278
28.	250000.	76.4	1.776	1.361	1.339	0.183	3.102	4.504
29.	300000.	76.6	1.853	1.423	1.443	0.194	3.242	4.734
30.	400000.	77.0	1.979	1.524	1.806	0.205	3.474	5.206
31.	500000.	77.0	2.074	1.600	1.944	0.214	3.704	5.698
32.	750000.	77.2	2.250	1.741	2.616	0.242	4.341	7.263
33.	1000000.	77.5	2.426	1.883	0.000	0.258	5.261	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

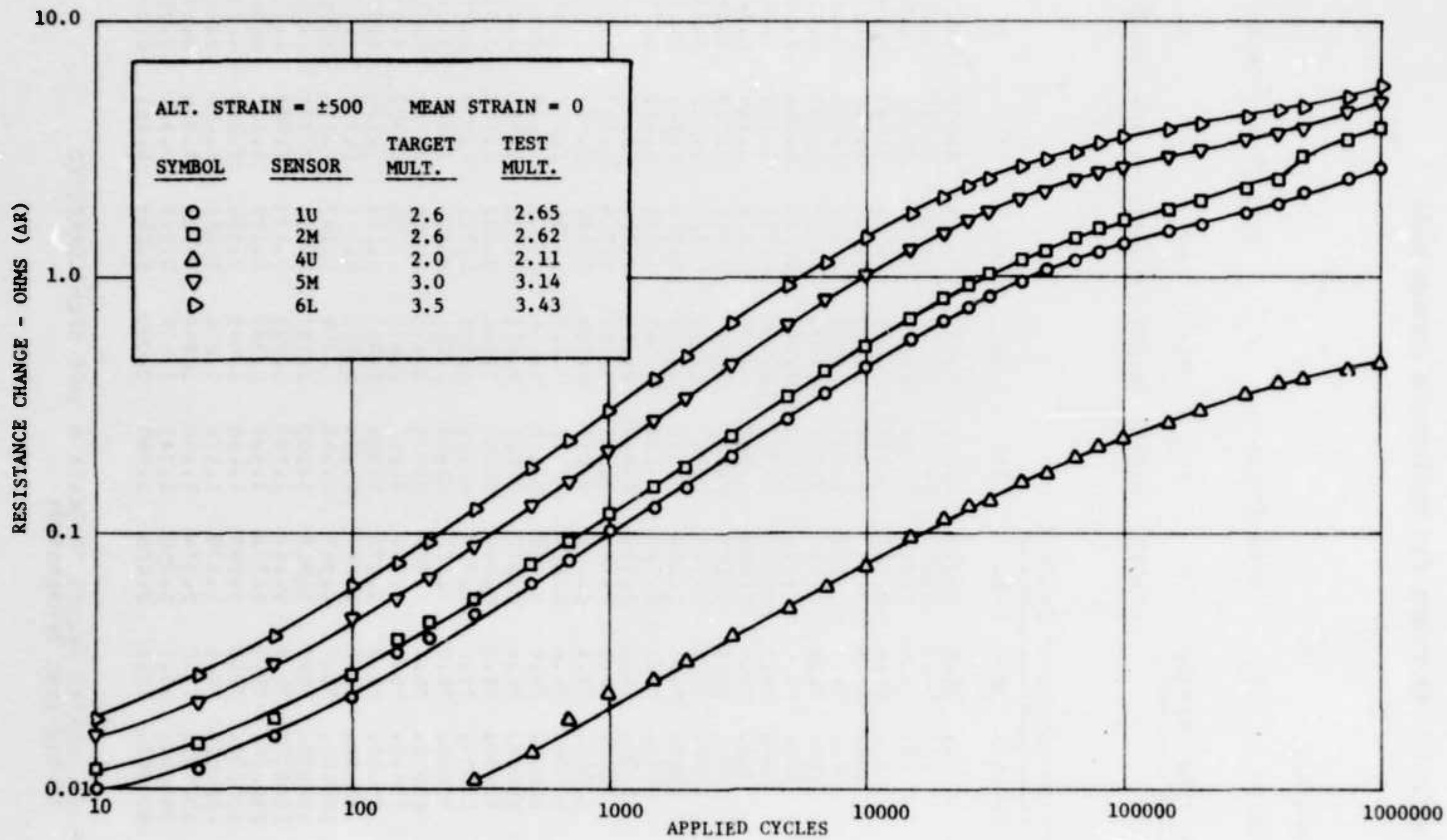

Figure 39 Specimen #1 Data Plot

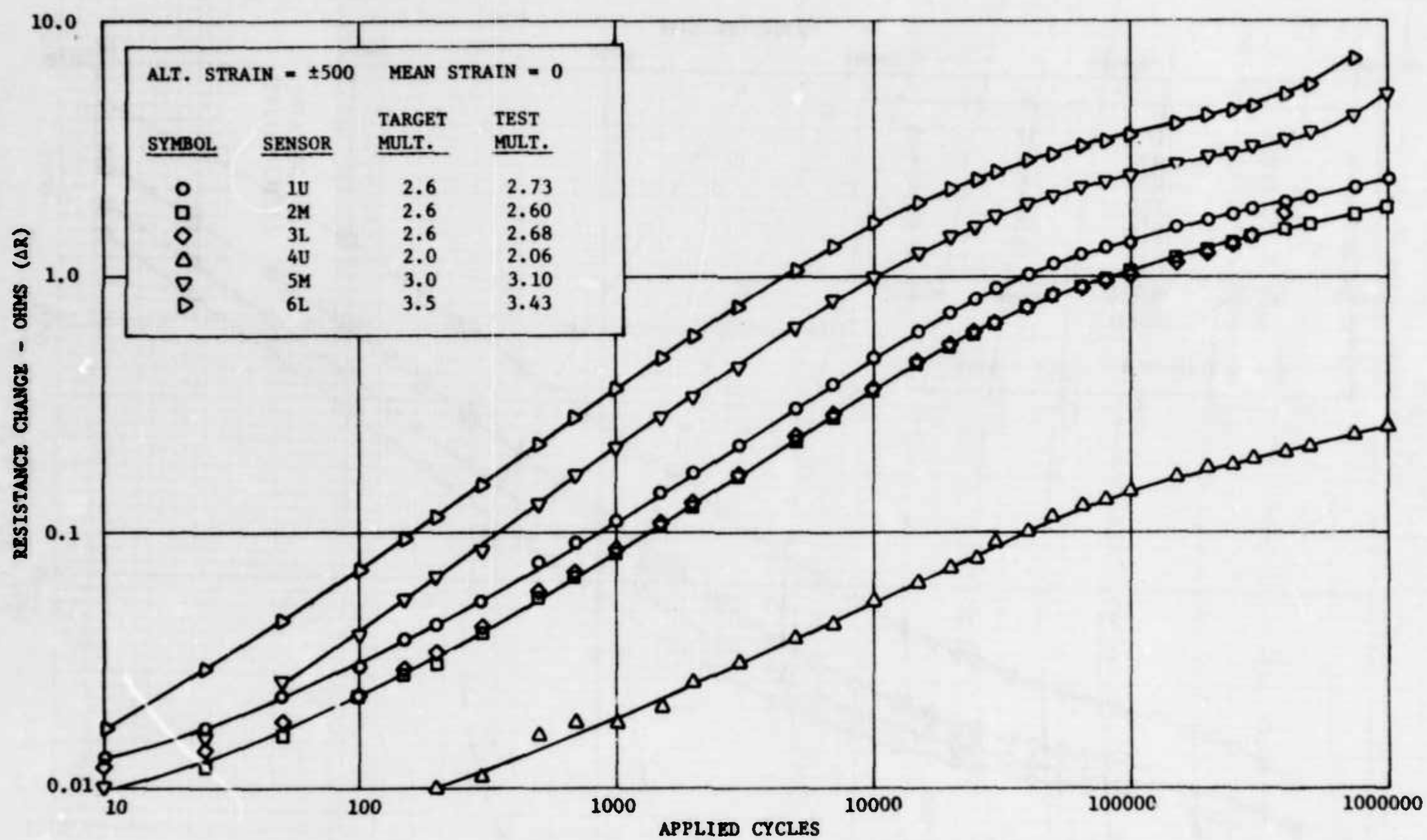

Figure 40 Specimen #33 Data Plot

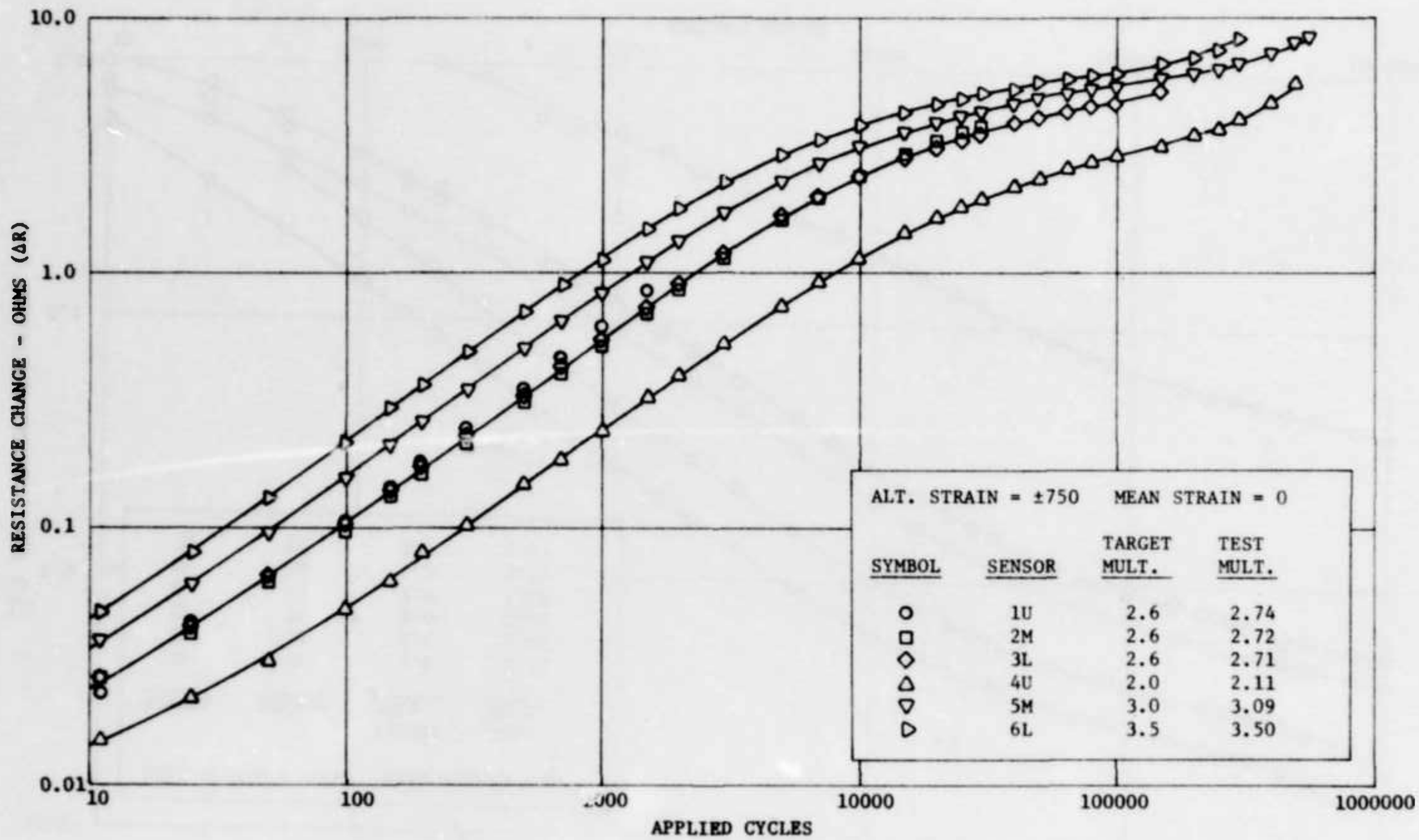

Figure 41 Specimen #2 Data Plot

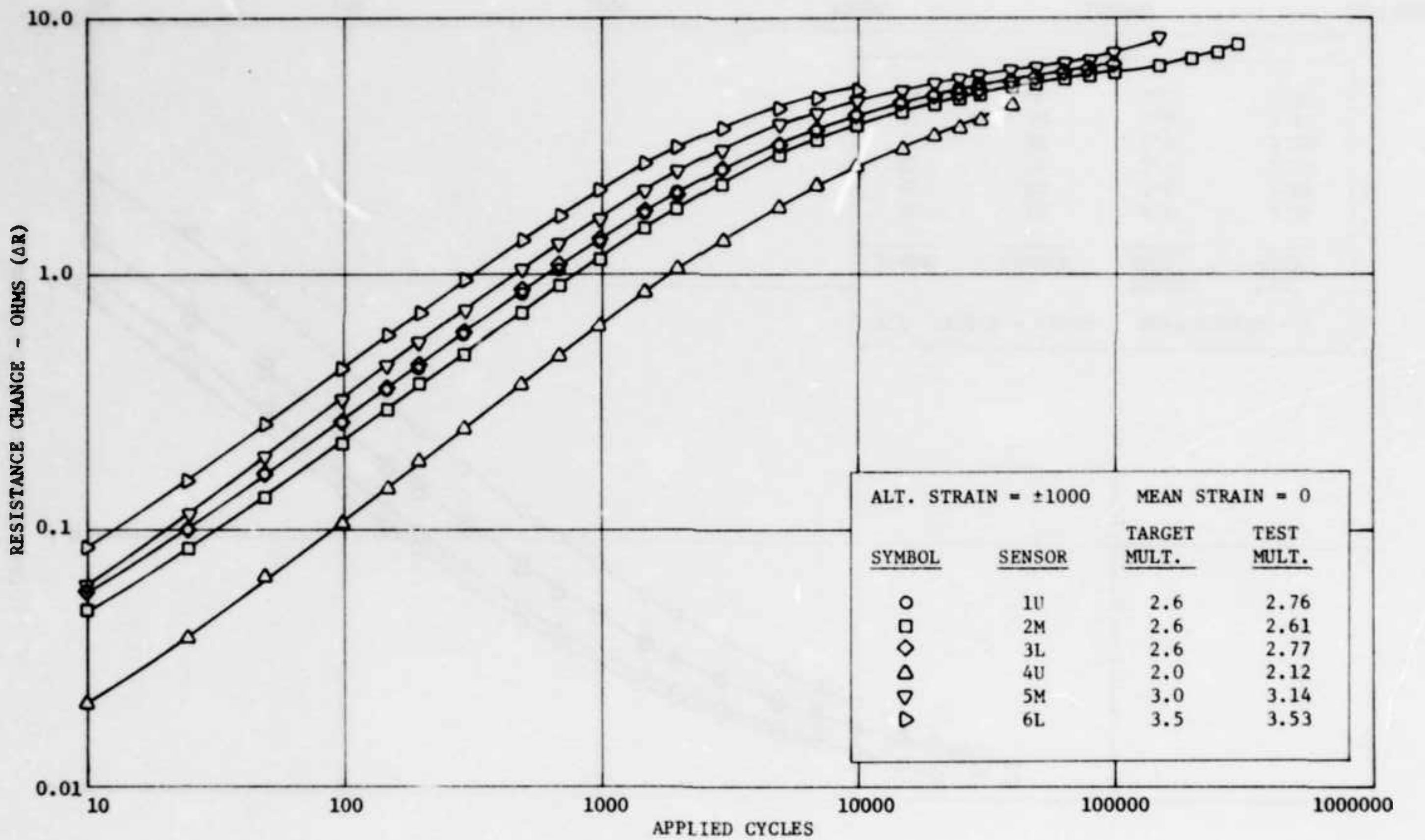

Figure 42 Specimen #3 Data Plot

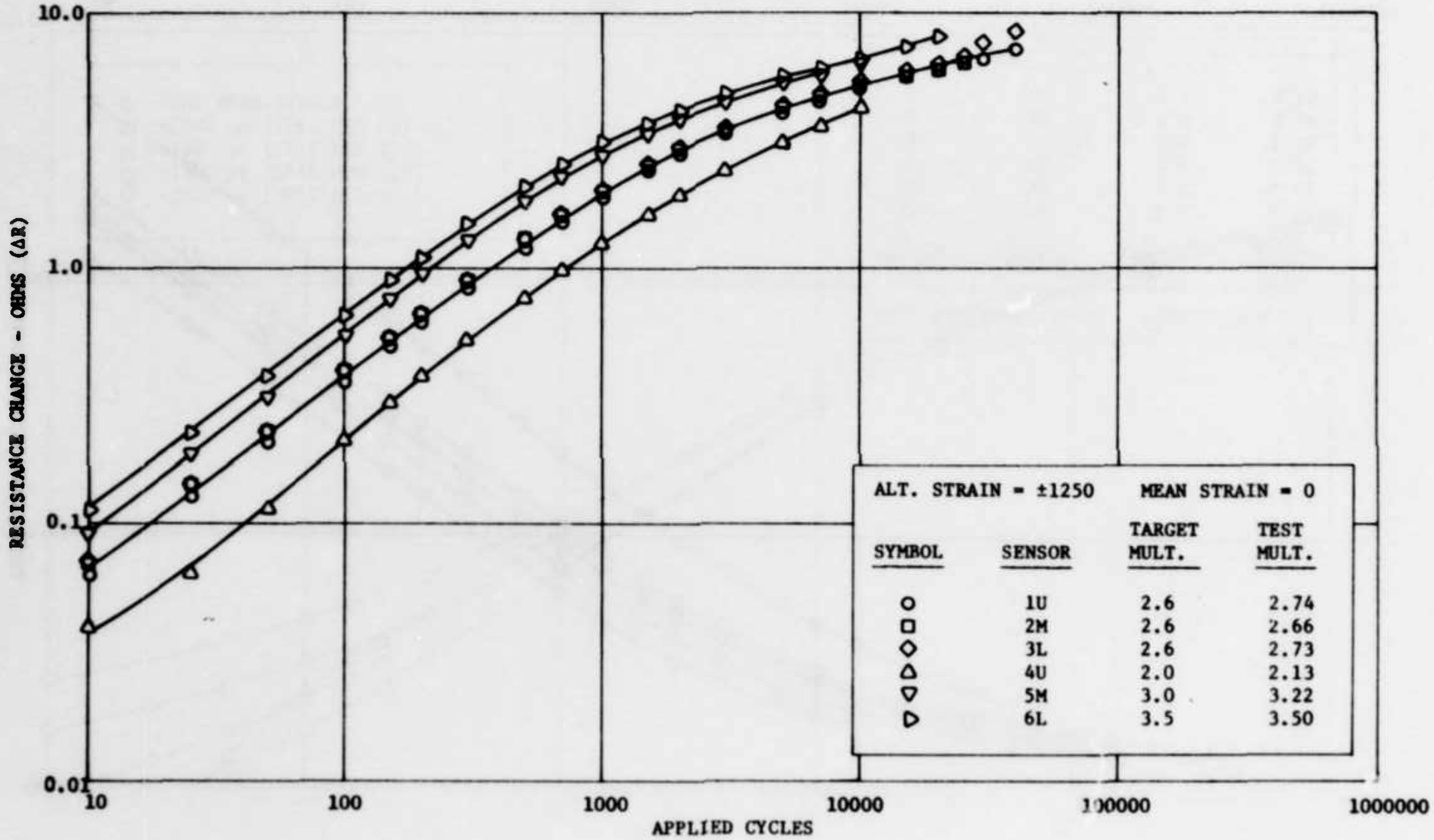

Figure 43 Specimen #4 Data Plot

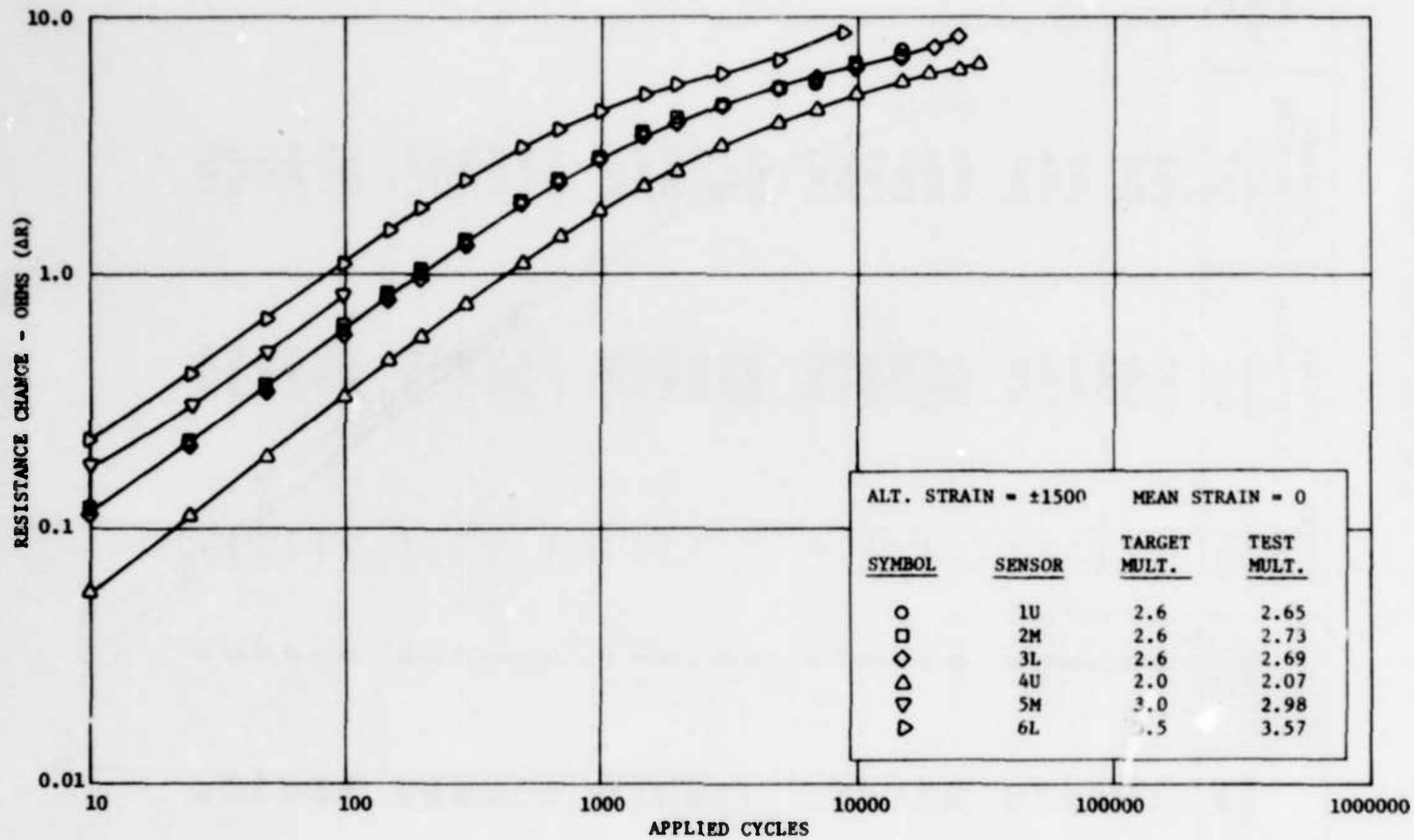

Figure 44 Specimen #5 Data Plot

TABLE 28 AVERAGE APPLIED STRAIN CYCLES FOR CONSTANT AMPLITUDE FATIGUE SENSORS

Spec No.	Sens No.	Target Mean Strain (με)	Average Mean Strain (με)	Target Alternating Strain (με)	Average Alternating Strain (με)	No. Of Data Points Included In Average
1	1U	0	--	1300	1318	9
	2M	0	--	1300	1315	9
	3L	0	--	1300	--	
	4U	0	--	1000	1042	7
	5M	0	--	1500	1544	9
	6L	0	--	1750	1694	9
2	1U	0	--	1950	2092	4
	2M	0	--	1950	2028	9
	3L	0	--	1950	1997	9
	4U	0	--	1500	1567	9
	5M	0	--	2250	2298	6
	6L	0	--	2625	2567	6
3	1U	0	--	2600	2763	3
	2M	0	--	2600	2612	3
	3L	0	--	2600	2754	3
	4U	0	--	2000	2065	3
	5M	0	--	3000	3092	8
	6L	0	--	3500	3472	4
4	1U	0	--	3250	3338	7
	2M	0	--	3250	3280	4
	3L	0	--	3250	3342	4
	4U	0	--	2500	2666	4
	5M	0	--	3750	4020	4
	6L	0	--	4375	4335	4
5	1U	0	--	3900	3934	5
	2M	0	--	3900	4007	9
	3L	0	--	3900	3958	6
	4U	0	--	3000	3047	6
	5M	0	--	4500	4551	1
	6L	0	--	5250	5279	3

TABLE 28 AVERAGE APPLIED STRAIN CYCLES FOR CONSTANT AMPLITUDE FATIGUE SENSORS (CONTINUED)

Spec No.	Sens No.	Target Mean Strain (με)	Average Mean Strain (με)	Target Alternating Strain (με)	Average Alternating Strain (με)	No. Of Data Points Included In Average
6	1U	2600	2661	1300	1325	9
	2M	2600	2641	1300	1303	9
	3L	2600	2681	1300	1324	9
	4U	2000	2039	1000	1007	9
	5M	3000	2941	1500	1459	9
	6L	3500	3426	1750	1711	9
7	1U	2600	2674	1950	2024	4
	2M	2600	2573	1950	1944	7
	3L	2600	2554	1950	1908	9
	4U	2000	2028	1500	1523	9
	5M	3000	2958	2250	2223	7
	6L	3500	3526	2625	2681	2
8	1U	2600	2708	2600	2708	6
	2M	2600	2608	2600	2608	6
	3L	2600	2602	2600	2602	9
	4U	2000	2112	2000	2112	6
	5M	3000	3057	3000	3057	6
	6L	3500	3559	3500	3559	6
9	1U	2600	--	3250	--	--
	2M	2600	2621	3250	3263	8
	3L	2600	2631	3250	3283	8
	4U	2000	2005	2500	2493	8
	5M	3000	3171	3750	3941	3
	6L	3500	3487	4375	4328	3
10	1U	2600	2560	3900	3832	4
	2M	2600	2573	3900	3873	4
	3L	2600	2643	3900	3883	4
	4U	2000	1280	3000	2065	4
	5M	3000	--	4500	--	
	6L	3500	--	5250	--	
11	1U	-2600	-2553	1300	1268	9
	2M	-2600	-2615	1300	1311	9
	3L	-2600	-2601	1300	1309	9
	4U	-2000	-2055	1000	1036	9
	5M	-3000	-3019	1500	1527	9
	6L	-3500	-3311	1750	1622	9

TABLE 28 AVERAGE APPLIED STRAIN CYCLES FOR CONSTANT AMPLITUDE FATIGUE SENSORS (CONTINUED)

Spec No.	Sens No.	Target Mean Strain ($\mu\varepsilon$)	Average Mean Strain ($\mu\varepsilon$)	Target Alternating Strain ($\mu\varepsilon$)	Average Alternating Strain ($\mu\varepsilon$)	No. Of Data Points Included In Average
12	1U	-2600	-2684	1950	2018	9
	2M	-2600	-2705	1950	2036	9
	3L	-2600	-2640	1950	1989	9
	4U	-2000	-2094	1500	1578	9
	5M	-3000	-3194	2250	2369	9
	6L	-3500	-3365	2625	2527	9
13	1U	-2600	-2666	2600	2666	8
	2M	-2600	-2766	2600	2766	8
	3L	-2600	-2584	2600	2584	8
	4U	-2000	-1990	2000	1990	8
	5M	-3000	-3030	3000	3030	8
	6L	-3500	-3233	3500	3233	8
14	1U	-1300	-1318	1300	1318	8
	2M	-1300	-1330	1300	1330	8
	3L	-1300	-1303	1300	1303	8
	4U	-1000	-1012	1000	1012	8
	5M	-1500	-1538	1500	1538	8
	6L	-1750	-1740	1750	1740	8
15	1U	-1300	-1287	1950	1936	8
	2M	-1300	-1275	1950	1924	8
	3L	-1300	-1278	1950	1934	8
	4U	-1000	-1026	1500	1549	8
	5M	-1500	-1529	2250	2310	8
	6L	-1750	-1740	2625	2635	8
16	1U	-1300	-1306	2600	2634	8
	2M	-1300	-1302	2600	2604	8
	3L	-1300	-1329	2600	2671	8
	4U	-1000	-1030	2000	2093	8
	5M	-1500	-1507	3000	3020	8
	6L	-1750	-1667	3500	3487	8
17	1U	-1300	-1294	3250	3379	8
	2M	-1300	-1292	3250	3325	8
	3L	-1300	-1249	3250	3258	8
	4U	-1000	-1054	2500	2647	8
	5M	-1500	-1674	3750	4125	5
	6L	-1750	-1777	4375	4544	5

TABLE 28 AVERAGE APPLIED STRAIN CYCLES FOR CONSTANT AMPLITUDE FATIGUE SENSORS (CONTINUED)

Spec No.	Sens No.	Target Mean Strain (με)	Average Mean Strain (με)	Target Alternating Strain (με)	Average Alternating Strain (με)	No. Of Data Points Included In Average
18	1U	-1300	-1316	3900	4003	4
	2M	-1300	-1335	3900	3990	4
	3L	-1300	-1326	3900	3912	4
	4U	-1000	-1031	3000	3058	6
	5M	-1500	-1643	4500	4839	4
	6L	-1750	-1738	5250	5260	4
19	1U	+1300	1324	1300	1324	7
	2M	+1300	1320	1300	1320	7
	3L	+1300	1317	1300	1317	7
	4U	+1000	998	1000	998	7
	5M	+1500	1519	1500	1519	7
	6L	+1750	1727	1750	1727	7
20	1U	+1300	1318	1950	1981	9
	2M	+1300	1297	1950	1940	9
	3L	+1300	1243	1950	1860	9
	4U	+1000	981	1500	1474	9
	5M	+1500	1462	2250	2192	9
	6L	+1750	1717	2625	2558	9
21	1U	+1300	1283	2600	2586	7
	2M	+1300	1307	2600	2611	7
	3L	+1300	1293	2600	2591	7
	4U	+1000	1007	2000	2004	7
	5M	+1500	1542	3000	3101	4
	6L	+1750	1786	3500	3578	4
22	1U	+1300	1298	3250	3286	5
	2M	+1300	1294	3250	3300	5
	3L	+1300	1354	3250	3427	3
	4U	+1000	1013	2500	2553	6
	5M	+1500	1519	3750	3849	3
	6L	+1750	1667	4375	4323	1

TABLE 28 AVERAGE APPLIED STRAIN CYCLES FOR CONSTANT AMPLITUDE FATIGUE SENSORS (CONCLUDED)

Spec No.	Sens No.	Target Mean Strain ($\mu\varepsilon$)	Average Mean Strain ($\mu\varepsilon$)	Target Alternating Strain ($\mu\varepsilon$)	Average Alternating Strain ($\mu\varepsilon$)	No. Of Data Points Included In Average
23	1U	+1300	1383	3900	4093	4
	2M	+1300	1383	3900	4063	4
	3L	+1300	1388	3900	4021	4
	4U	+1000	1015	3000	2992	6
	5M	+1500	--	4500	--	-
	6L	+1750	1848	5250	5371	4
33	1U	0	--	1300	1334	9
	2M	0	--	1300	1268	6
	3L	0	--	1300	1278	6
	4U	0	--	1000	1003	9
	5M	0	--	1500	1538	9
	6L	0	--	1750	1720	7

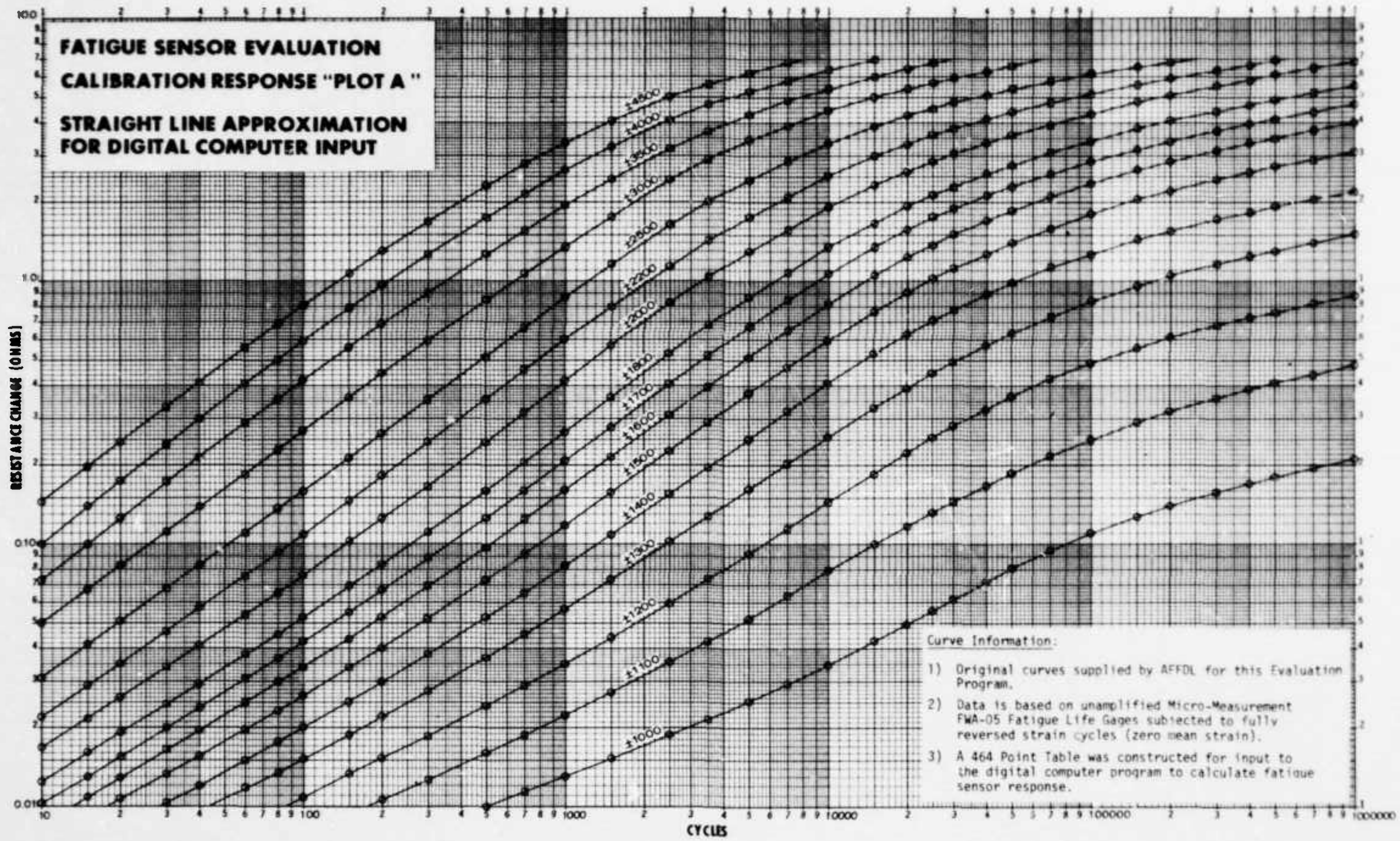

Figure 45 Micro-Measurements Calibration Data

SECTION IV

MEAN STRAIN RESPONSE

4.1 INTRODUCTION

Fatigue sensor response to mean strain is developed using data from 18 constant amplitude specimens (#6 thru #23). Fatigue sensors operated at 17 amplified levels of mean strain ranging from +3500 to -3500 $\mu\varepsilon$. Mean strain response data are compared to zero mean "calibration" response developed by Section III.

4.2 DATA ANALYSES

4.2.1 Data Parameters

Mean strain data analyses are based on fatigue sensor resistance change (ΔR) data from constant amplitude test specimens #6 thru #23 (documented by Tables E-1 thru E-18).

The addition of a fourth parameter, mean strain, to the three already utilized in the analysis of section 3.2.1, made it necessary to fix an additional parameter, in order that the data could be analyzed by a two dimensional plotting system. Alternating strain was the selected parameter. To make alternating strain a constant, target values of alternating strain were selected and all values of ΔR were adjusted to the value which would have been obtained if the sensor had been operating at the target value of alternating strain.

The mean strain analysis/adjustment procedure used the average alternating strain and average mean strain calculated for each sensor by the method outlined in paragraph 3.2.1. Average strain values for specimens #6 thru #23 are included in Table 28. Note: Average mean strain data for specimens #6 thru #23 are calculated using the same process as outlined for average alternating strain (see 3.2.1).

4.2.2 Data Adjustment

The average alternating strain and resistance change (ΔR) parameters from test data (Tables E-1 thru E-18) were adjusted to standard values of alternating strain using the basic zero mean strain calibration curves developed by Section III (Figure 36).

An assumption was made that the alternating strain versus ΔR curves for sensors with applied mean strain would have the same slope as those for sensors with zero mean strain (Figure 36). Sufficient data were checked to assure the error introduced by this assumption was negligible.

An example of the alternating strain adjustment process is presented graphically for sensor 3L, specimen #9, at 50 cycles, by Figure 46 :

1. The raw data point "A" (alternating strain = 3283, ΔR = .2111) is superimposed on the 50 cycle, zero mean strain curve (see Figure 36 for family of curves).

2. Point "C" on the curve is established at the same alternating strain as Point "A".

3. Point "B" on the curve at the target alternating strain of 3000 is established and the line segment "B-C" is constructed through these points.

4. A line parallel to "B-C" is constructed through Point "A" and extended to intersect the target strain line (3000 $\mu\varepsilon$) at Point "D".

5. The adjusted value shown in Table E-21 is Point "D" (alternating strain = 3000, ΔR = .1704).

A computer program was developed to accomplish the adjustment procedure analytically using the curve fit equations described by section 3.2.3. Test data for specimens #6 thru #23 were adjusted to twelve constant levels of alternating strain at 15 cyclic levels. These data are presented by Tables E-19 thru E-33.

4.2.3 <u>Data Plots</u>

Adjusted data (Tables E-19 thru E-33) were plotted to determine the effect of mean strain using two methods:

a) Plot family of alternating strain curves with resistance change versus mean strain. Number of applied cycles is held constant. Figures 47 thru 50 present data plotted by this method.

b) Plot family of mean strain curves with resistance change versus applied cycles. Alternating strain is held constant. Figures 51 thru 53 present data plotted by this method.

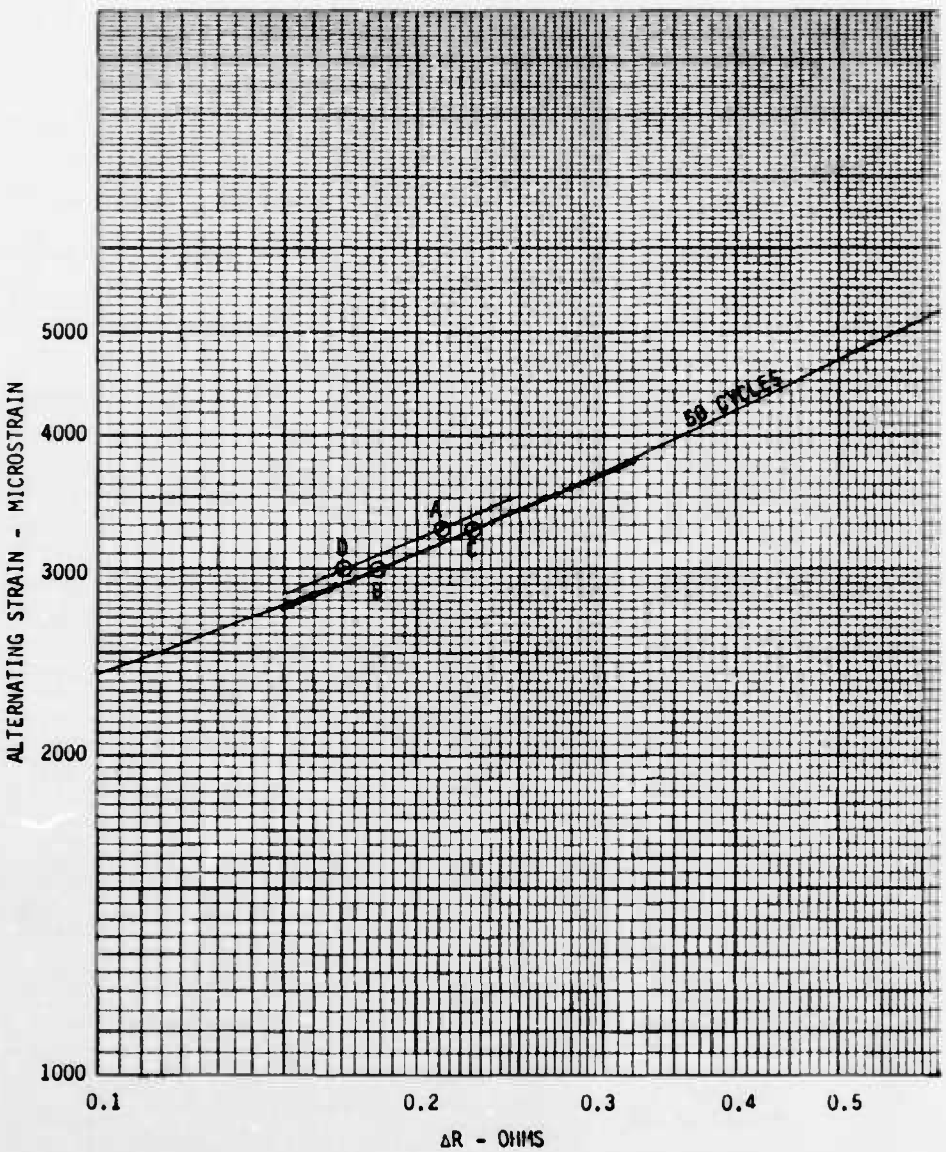

Figure 46 Adjustment Technique
Mean Strain Data

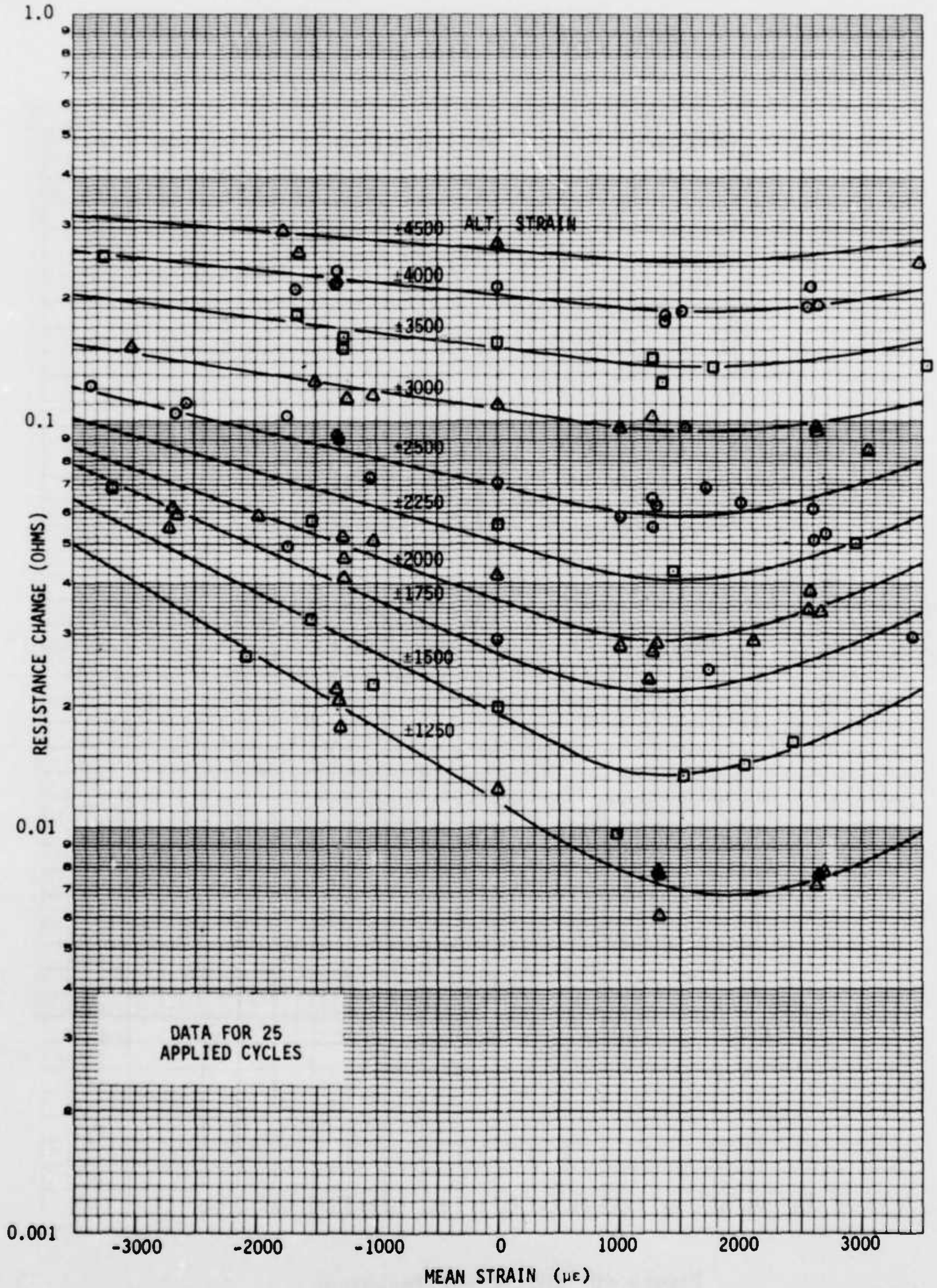

Figure 47 Mean Strain Response At 25 Cycles

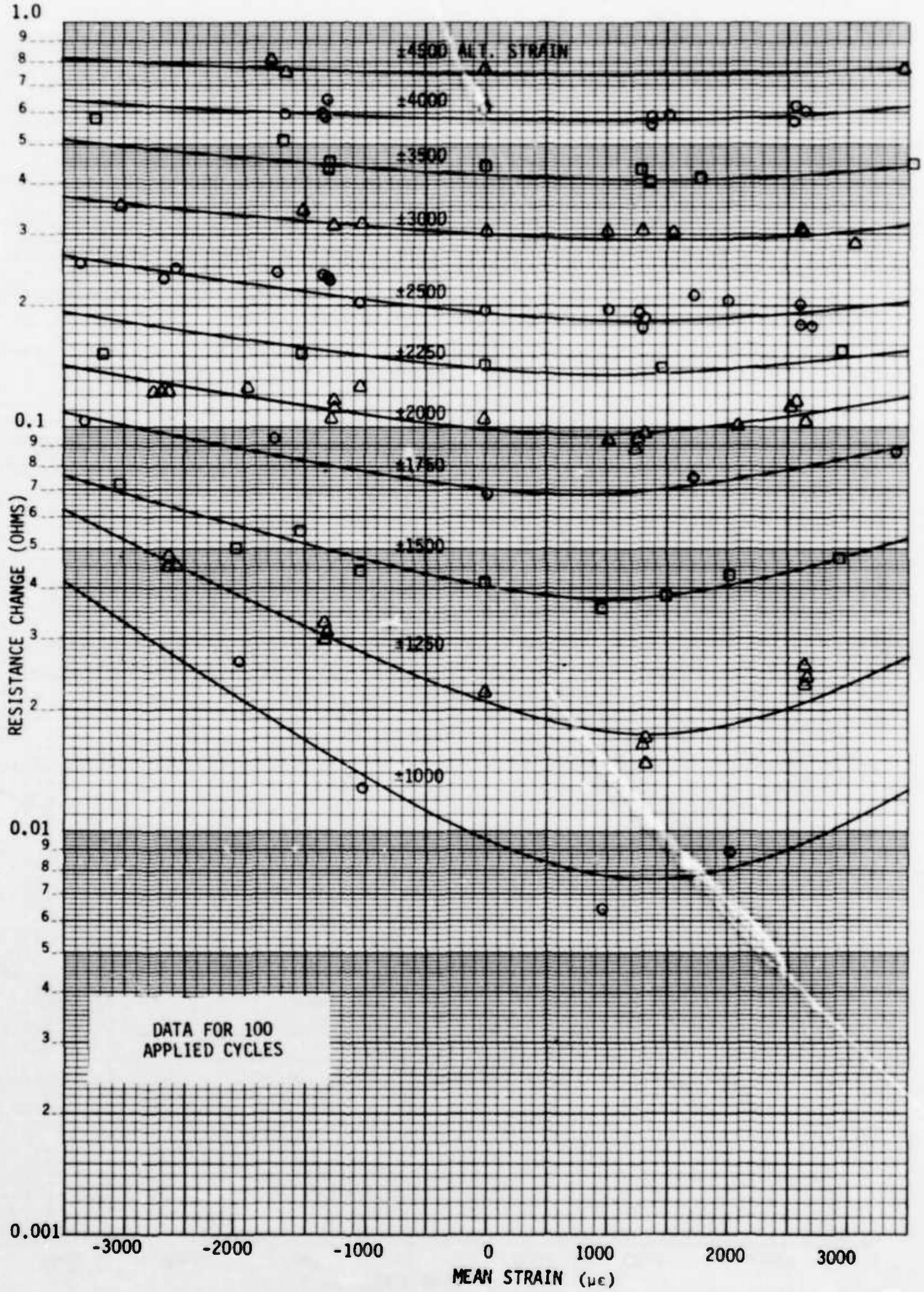

Figure 48 Mean Strain Response At 100 Cycles

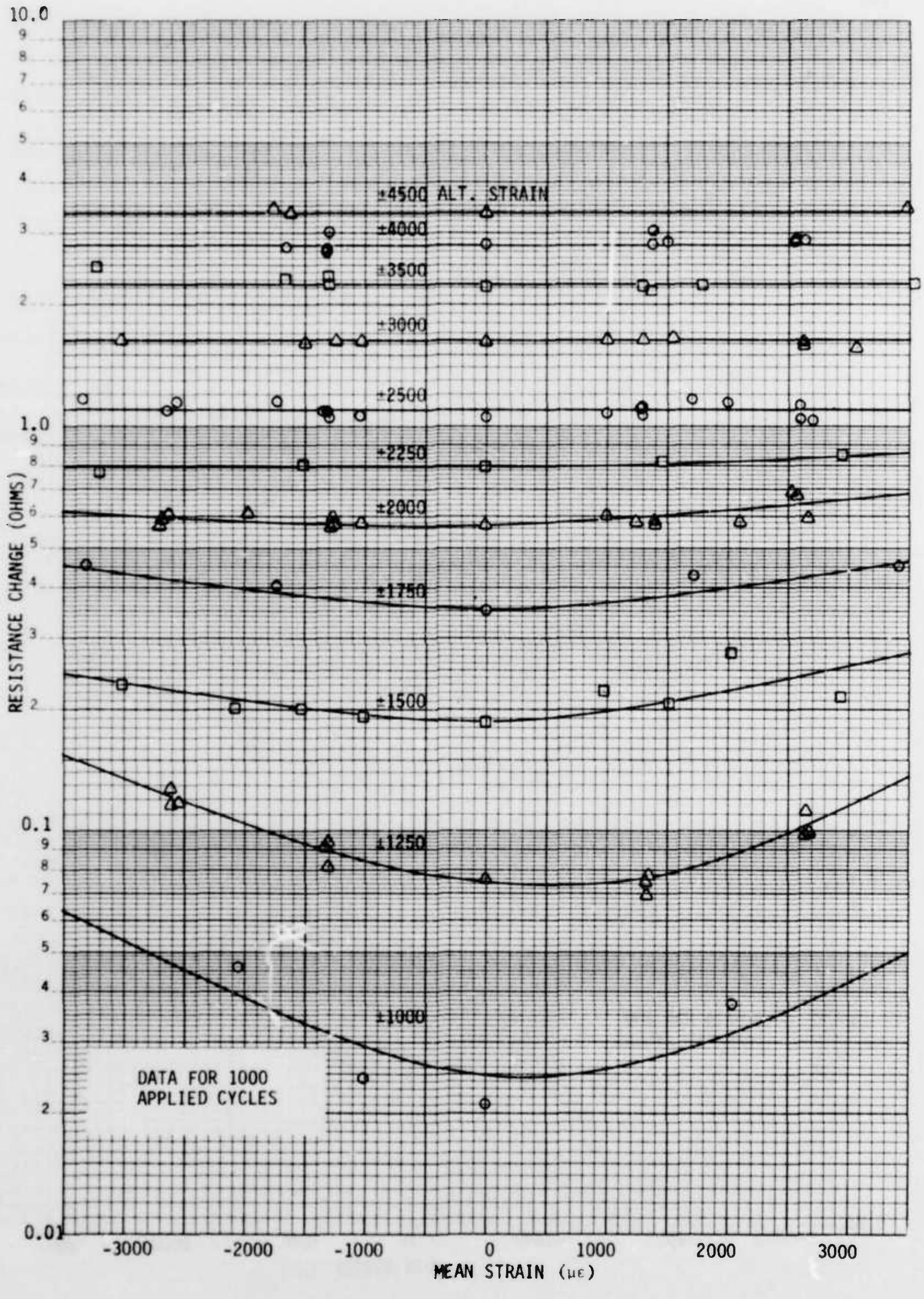

Figure 49 Mean Strain Response At 1000 Cycles

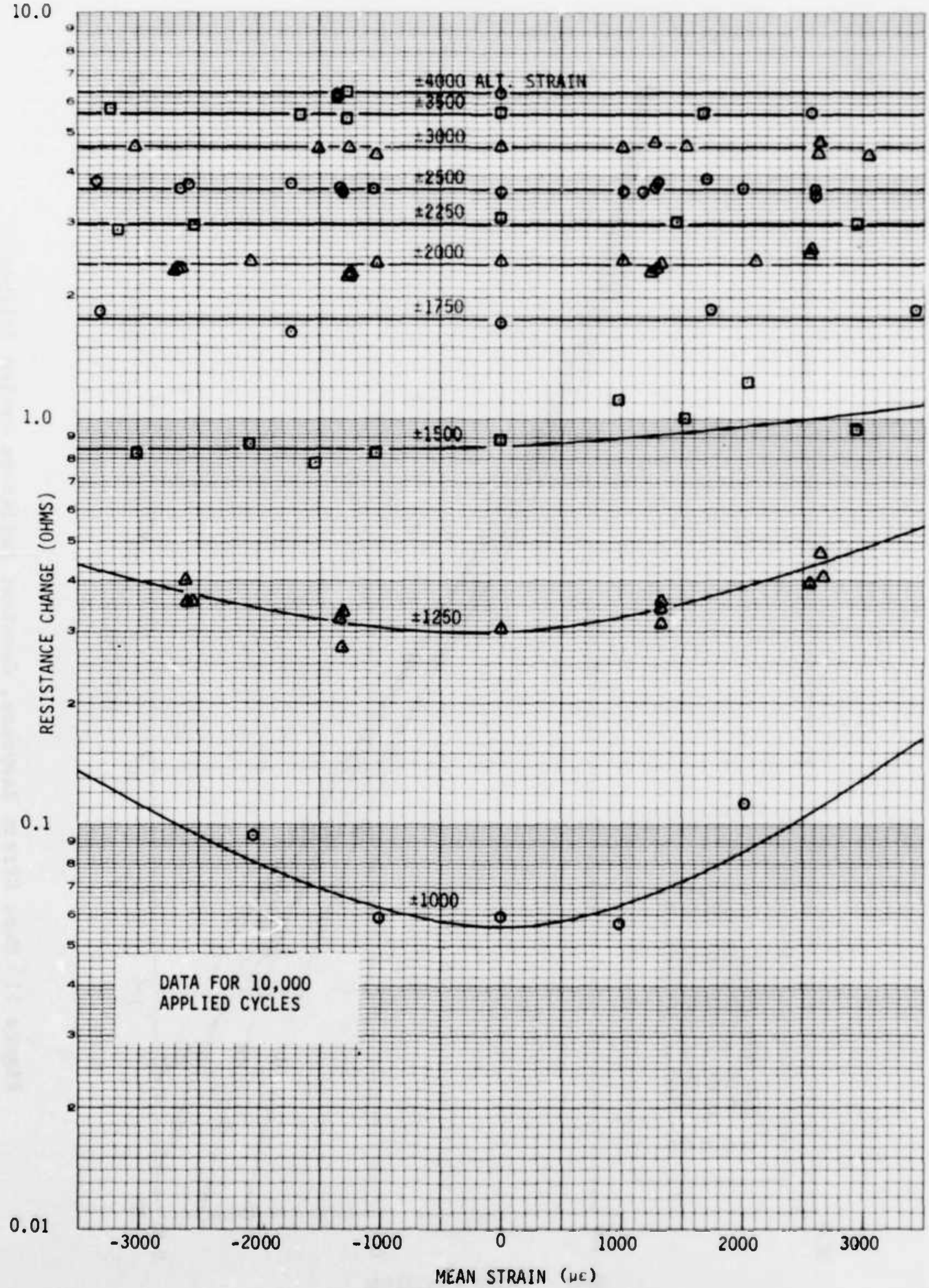

Figure 50 Mean Strain Response At 10000 Cycles

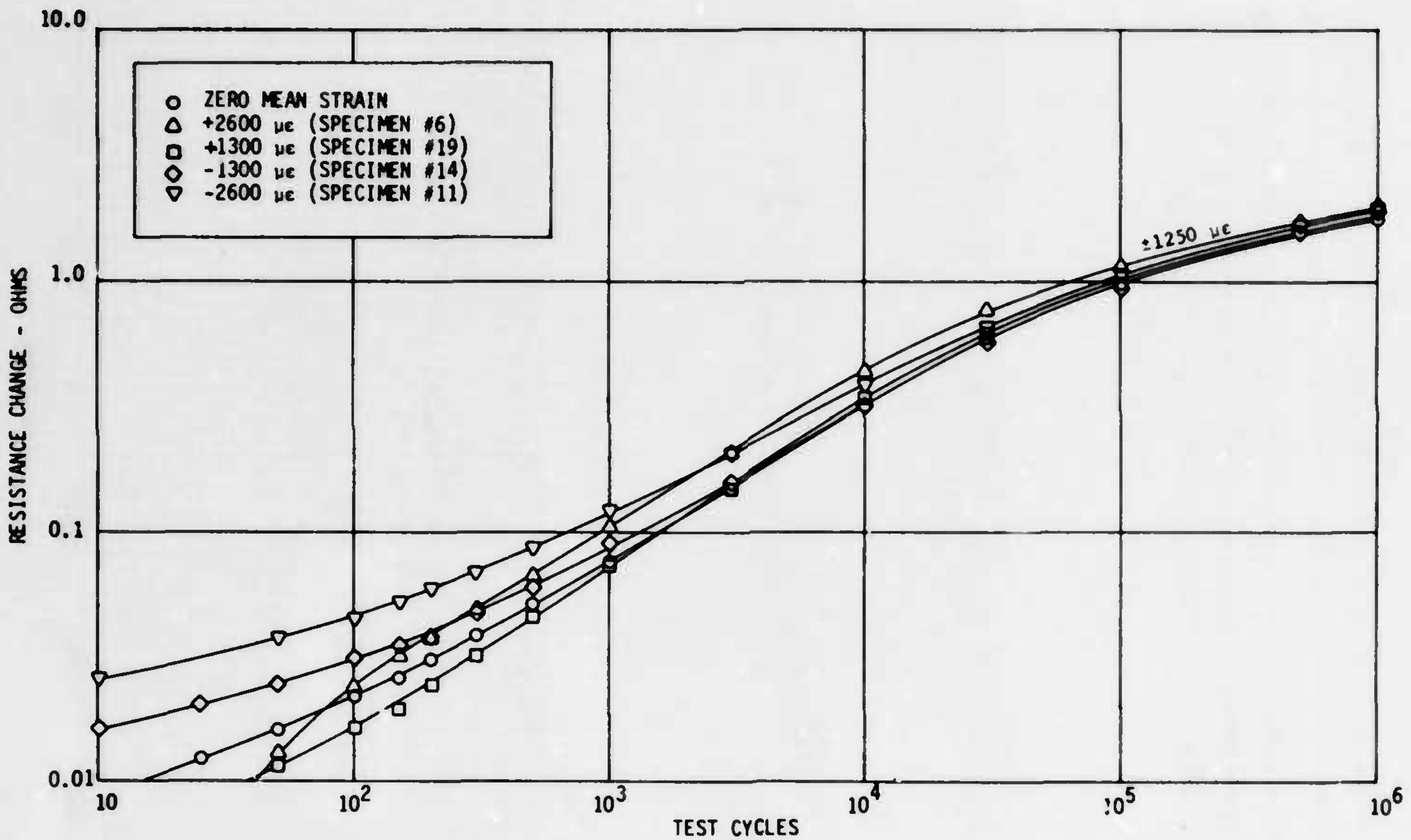

Figure 51 Mean Strain Response, Constant Amplitude Cycles (±1250με)

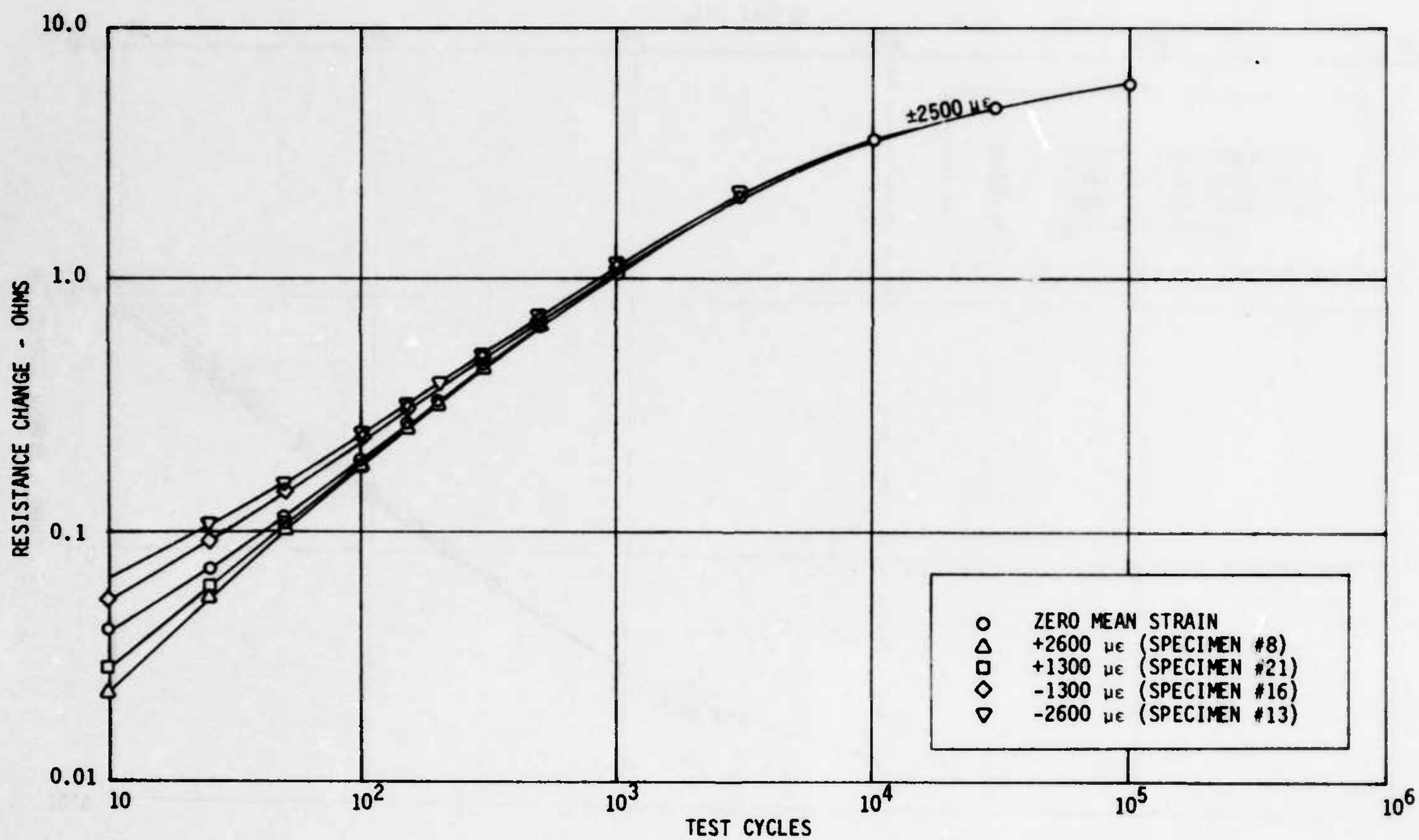

Figure 52 Mean Strain Response, Constant Amplitude Cycles (±2500με)

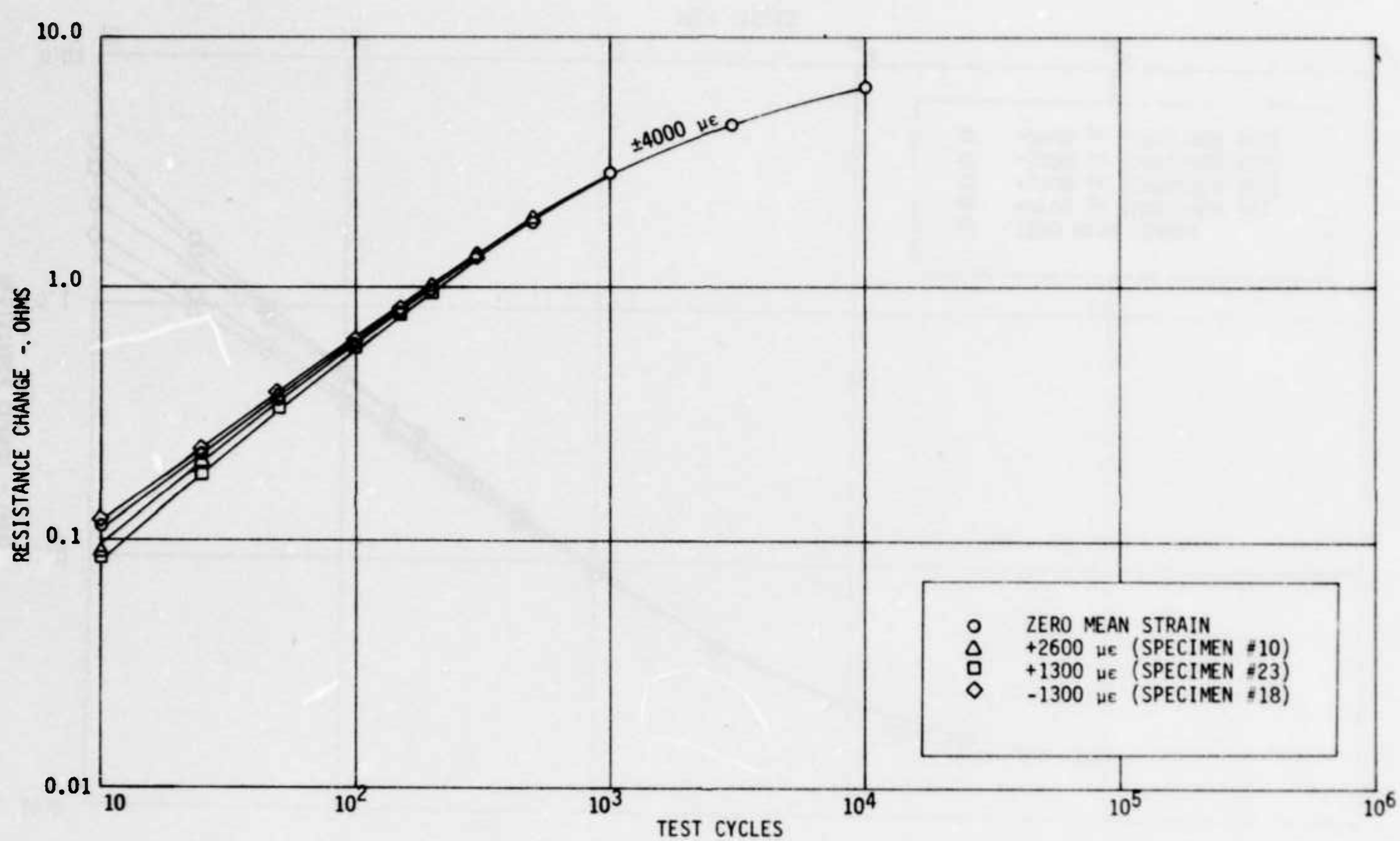

Figure 53 Mean Strain Response, Constant Amplitude Cycles (±4000με)

4.3 RESULTS

Mean strain data analyses have indicated the following effects of applied mean strain on fatigue sensor response (as evidenced by data plots presented):

a) The effect of mean strain decreases as the number of applied cycles increases. Mean strain tends to become insignificant after 100 applied cycles.

b) The effect of mean strain decreases as the level of alternating strain increases. Mean strain tends to become insignificant for fatigue sensor alternating strains above ±1500 με.

c) In the region where mean strain has an effect, compression mean strain increases ΔR (fatigue sensor response) and tension mean strain decreases ΔR.

The effect of mean strain is summarized from basic test data by noting the overall response of 24 fatigue sensors cycled in pure compression (specimen #11 thru #14) compares well with 24 sensors cycled in pure tension (specimen #6, #7, #8, #19) using equal and opposite load cycles. Table 29 presents this data comparison.

4.4 DATA REPEATABILITY AND FAILURE MODE

Data scatter and repeatability of fatigue sensors are graphicaly represented by the data plots, Figures 47 thru 53. While no formal scatter analysis was performed on the mean strain data, examination of the data plots reveals no contridiction of the conclusions in paragraph 3.3. The failure mode analysis of paragraph 3.4 included the mean strain specimens.

TABLE 29

MEAN STRAIN EFFECTS USING EQUAL AND OPPOSITE COMPRESSION AND TENSION STRAIN CYCLES

Mean strain effects on fatigue sensor response using equal and opposite load cycles (data from Appendix E resistance change data for individual specimens, Table E-1 thru E-18).

A. At 100 Applied Cycles

Spec.	Alt. Strain	Mean Strain	ΔR*
6	±500	+1000	0.029
11	±500	-1000	0.045
7	±750	+1000	0.104
12	±750	-1000	0.128
8	±1000	+1000	0.215
13	±1000	-1000	0.257
19	±500	+500	0.020
14	±500	-500	0.038

B. At 1000 Applied Cycles

Spec.	Alt. Strain**	Mean Strain**	ΔR*
6	±500	+1000	0.136
11	±500	-1000	0.146
7	±750	+1000	0.607
12	±750	-1000	0.604
8	±1000	+1000	1.214
13	±1000	-1000	1.226
19	±500	+500	0.098
14	±500	-500	0.118

*Average of sensors 1U, 2M, 3L (Mult = 2.5).

**Strains listed are applied specimen strain; for fatigue sensor operating strain see Table 28.

SECTION V

SPECTRUM LOAD RESPONSE

5.1 DATA ANALYSES

Data analyses of spectrum loaded specimens (#24 and #25) consisted of plotting fatigue sensor response and comparing response for two different orders of cycle application. Figures 54 and 55 plot sensor response data (data from Table 30 and 31) and Table 32 compares response at selected cyclic intervals. This comparison shows fatigue sensor response to be virtually identical for both specimens. Data plots also indicate the alteration from high to low severity cycle application resulted in corresponding adjustments of fatigue sensor response rate.

The load cycle response data collected for specimens #24 and #25 indicate the spectrum loading had no adverse effect on FM multiplier performance or stability; multiplier operation was comparable to constant amplitude specimens.

5.2 PREDICTION OF RESPONSE

A prediction of fatigue sensor response was made for each spectrum loaded specimen using the method outlined by Appendix A. The prediction was based on a NLR[a] cycle count (Reference 6) of applied cycles as modified by Cessna to be similar to Reference 7 and constant amplitude "calibration" response data. The NLR cycles used for prediction are presented by Table 33 and 34 on an individual "flight" basis. (Note: The NLR cycle count was made on a per layer basis to help account for effects of transition half cycles). The actual test multiplier (sample calculation Appendix F) was used to adjust applied strain cycles for prediction of individual sensor/multiplier response. Fatigue sensor predicted response is compared to actual response for the 2.5 multiplier in Figures 56 and 57.

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[a]NLR - The range pair type cycle count method developed by Reference 6.

Reference 6. - de Jonge, J. B., "The Monitoring of Fatigue Loads", National Aerospace Laboratory NLR, MP70010U.

Reference 7. - Tischler, V. A., A Computer Program for Counting Load Spectrum Cycles Based on the Range Pair Cycle Counting Method, TM-FBR-72-4, Air Force Flight Dynamics Laboratory, Dayton, Ohio, November 1972.

5.3 RESULTS

a) Fatigue sensor response was virtually the same for specimens #24 and #25. It is analytically possible to arbitrarily order the load applications in a spectrum in such a manner as to affect the ΔR generated by the spectrum. However, this test helps confirm the analytical investigation, which concluded that any random ordering or natural distribution of load applications will give practically identical results.

b) Adjustments in severity of cycle application resulted in corresponding changes in fatigue sensor response rate.

c) The response prediction was consistently below actual response (10-20%). It was determined experimentally that an increase in strain used for the prediction of 6 to 9% would give substantial agreement between predicted and actual response. It seems probable that this discrepancy is due to a basic deficiency in the NLR cycle counting method.

TABLE 30 SPECIMEN #24 RESISTANCE CHANGE DATA

SPECIMEN NO. = 24

SPECTRUM LOADED TEST ZERO TEMP = 73.0

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.250	-0.568	-0.506	-0.605	-0.707	0.011

CALCULATED VALUES OF DELTA R

READ.	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	73.6	0.010	0.009	0.010	0.003	0.014	0.022
2.	25.	73.6	0.027	0.026	0.026	0.015	0.035	0.049
3.	50.	73.5	0.033	0.032	0.033	0.018	0.050	0.070
4.	102.	73.8	0.054	0.052	0.054	0.025	0.085	0.121
5.	151.	73.9	0.085	0.084	0.088	0.042	0.135	0.187
6.	200.	73.9	0.107	0.107	0.110	0.054	0.171	0.235
7.	301.	73.9	0.140	0.141	0.145	0.070	0.229	0.313
8.	451.	73.9	0.193	0.196	0.202	0.097	0.321	0.431
9.	600.	73.9	0.242	0.246	0.252	0.122	0.403	0.536
10.	900.	73.7	0.298	0.306	0.312	0.150	0.503	0.669
11.	1200.	73.7	0.350	0.361	0.367	0.176	0.598	0.791
12.	1800.	73.6	0.443	0.461	0.468	0.220	0.767	1.011
13.	3000.	73.8	0.653	0.680	0.691	0.324	1.123	1.457
14.	4200.	73.7	0.893	0.930	0.942	0.455	1.496	1.901
15.	6000.	74.0	1.214	1.262	1.278	0.633	1.973	5.645
16.	9900.	74.0	1.522	1.586	1.607	0.801	2.432	0.0
17.	13500.	74.2	1.757	1.830	1.859	0.933	2.760	0.0
18.	19500.	74.2	2.077	2.163	2.201	1.125	3.184	0.0
19.	24600.	75.0	2.317	2.408	2.455	1.282	3.473	0.0
20.	30000.	74.5	2.681	2.773	2.828	1.548	3.884	0.0
21.	39000.	74.7	3.140	3.228	3.295	1.908	4.361	0.0
22.	49500.	74.7	3.536	3.622	3.696	2.247	4.761	0.0
23.	64500.	74.7	3.876	3.956	4.036	2.565	5.091	0.0
24.	79500.	74.7	4.030	4.128	4.194	2.707	5.249	0.0
25.	99900.	75.0	4.196	4.292	4.364	2.869	5.424	0.0
26.	150000.	74.3	4.499	4.575	4.686	3.161	5.784	0.0
27.	199500.	73.4	4.739	4.778	4.937	3.380	6.080	0.0
28.	249000.	73.4	4.991	5.008	5.196	3.603	6.584	0.0
29.	300000.	74.2	5.455	5.530	5.697	3.990	7.648	0.0
30.	405000.	74.6	6.459	7.084	6.809	4.559	0.0	0.0
31.	539700.	74.7	7.306	8.911	7.672	5.282	0.0	0.0
32.	750000.	74.1	0.0	0.0	0.0	0.0	0.0	0.0

NOTE— CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE 31 SPECIMEN #25 RESISTANCE CHANGE DATA

SPECIMEN NO. = 25

SPECTRUM LOADED TEST ZERO TEMP = 73.6

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.451	-0.423	-0.578	-0.263	-0.240	-0.257

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L*	4U	5M	6L
1.	12.	74.7	0.001	-0.001	-0.018	-0.003	0.002	0.010
2.	25.	74.7	0.016	0.015	-0.019	0.006	0.026	0.040
3.	50.	74.7	0.021	0.019	-0.006	0.007	0.033	0.057
4.	104.	74.8	0.046	0.043	0.008	0.019	0.072	0.115
5.	153.	74.7	0.073	0.067	0.016	0.031	0.112	0.175
6.	204.	74.5	0.091	0.085	0.020	0.040	0.138	0.215
7.	300.	74.5	0.125	0.119	0.042	0.055	0.192	0.297
8.	453.	74.5	0.189	0.177	0.104	0.085	0.284	0.432
9.	600.	74.5	0.237	0.223	0.121	0.107	0.356	0.539
10.	900.	74.3	0.325	0.306	0.204	0.145	0.488	0.735
11.	1200.	74.4	0.389	0.365	0.358	0.174	0.579	0.867
12.	1800.	74.4	0.491	0.459	1.094	0.214	0.730	1.091
13.	3000.	74.5	0.725	0.679	3.749	0.322	1.060	1.559
14.	4200.	74.5	0.972	0.913	0.0	0.445	1.396	2.005
15.	6000.	74.5	1.308	1.233	0.0	0.619	1.838	2.558
16.	9900.	74.8	1.655	1.559	0.0	0.780	2.279	3.088
17.	13500.	74.9	1.891	1.782	0.0	0.895	2.567	3.428
18.	19500.	74.2	2.247	2.115	0.0	1.076	2.985	3.881
19.	24600.	73.7	2.496	2.359	0.0	1.228	3.270	4.835
20.	30000.	74.2	2.871	2.727	0.0	1.491	3.689	0.0
21.	39000.	74.4	3.337	3.184	0.0	1.844	4.207	0.0
22.	49500.	75.3	3.708	3.554	0.0	2.150	4.561	0.0
23.	64500.	75.6	4.029	3.876	0.0	2.434	4.912	0.0
24.	79500.	74.1	4.223	4.060	0.0	2.578	5.164	0.0
25.	99900.	75.8	4.400	4.234	0.0	2.728	5.358	0.0
26.	150000.	75.4	4.731	4.555	0.0	2.993	5.903	0.0
27.	199500.	75.8	4.984	4.808	0.0	3.187	6.295	0.0
28.	249000.	76.1	5.263	5.120	0.0	3.382	6.625	0.0
29.	300000.	76.2	5.805	5.773	0.0	3.756	7.423	0.0
30.	405000.	76.1	7.016	7.594	0.0	4.268	8.863	0.0
31.	495000.	76.7	10.011	0.0	0.0	4.727	0.0	0.0
32.	750000.	77.4	0.0	0.0	0.0	6.037	0.0	0.0
32.	950400.	74.5	0.0	0.0	0.0	8.425	0.0	0.0

NOTE— CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

*Defective sensor (premature failure).

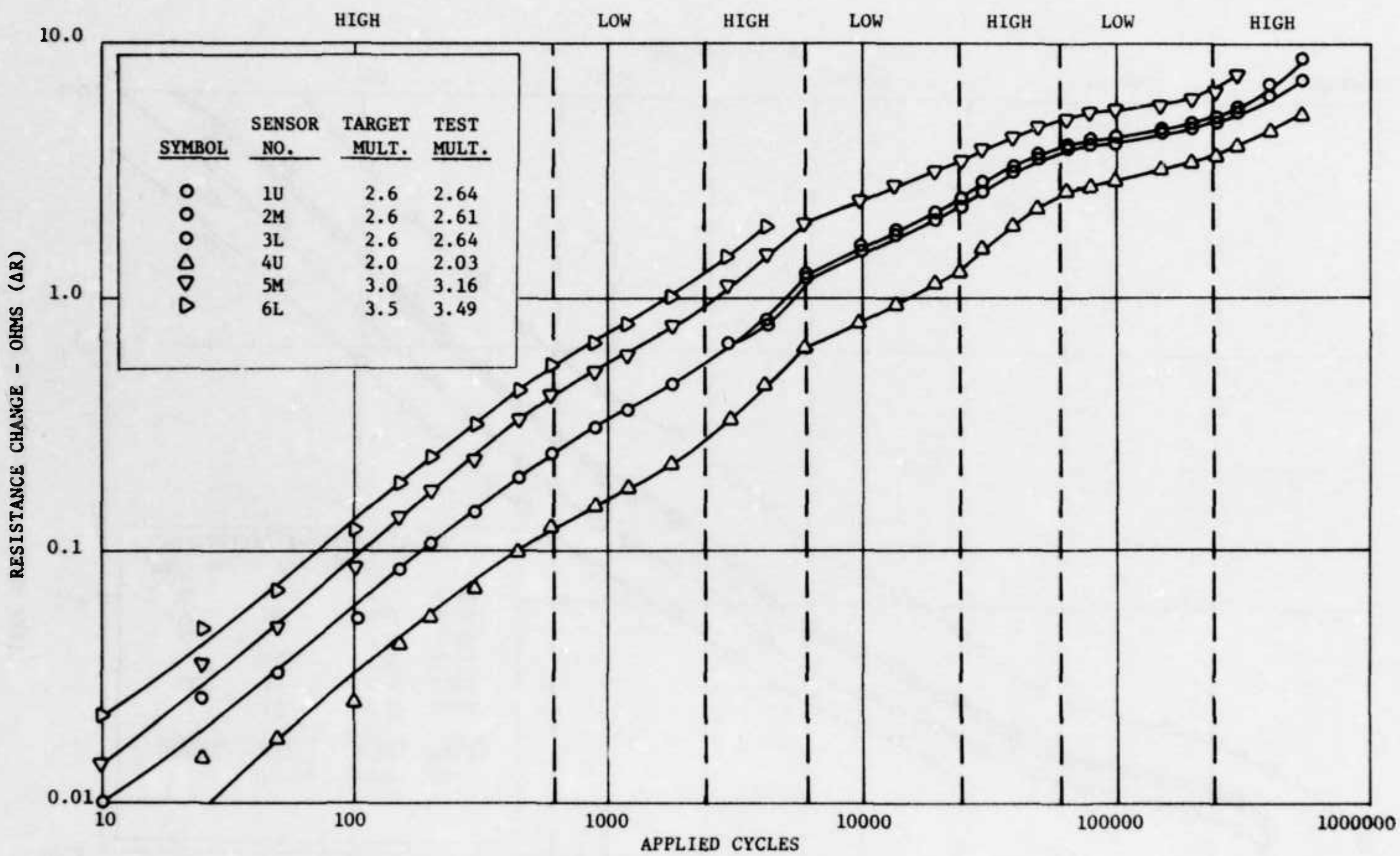

Figure 54 Spectrum Test Data Plot, Specimen #24

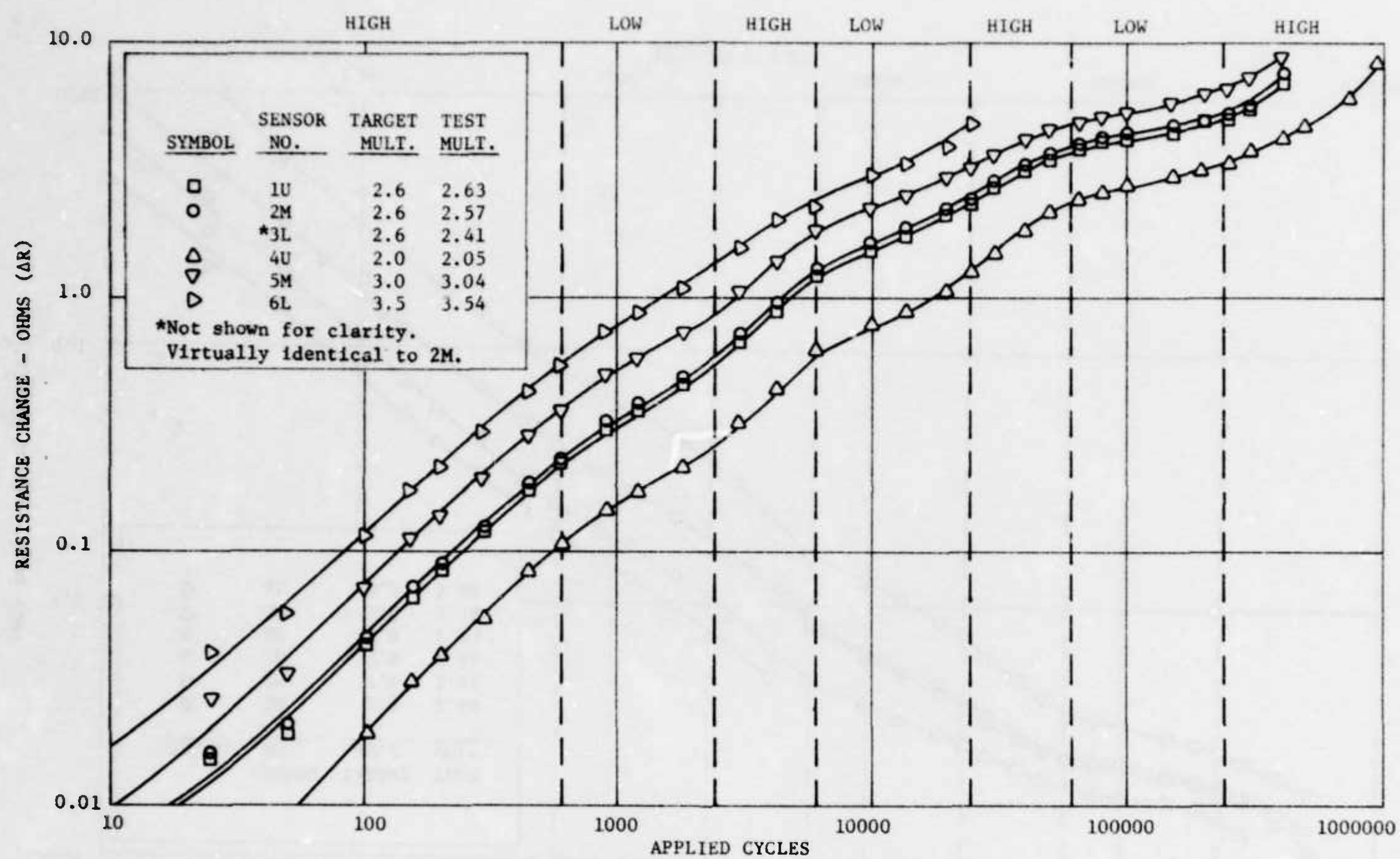

Figure 55 Spectrum Test Data Plot, Specimen #25

TABLE 32 COMPARISON OF FATIGUE SENSOR RESPONSE FOR RANDOM LOAD APPLICATION

	Resistance Change - Ohms		
Specimen	#24/#25	#24/#25	#24/#25
Mult.	2.0	2.5*	3.0
100 Cycles	0.032/0.019	0.060/0.043	0.092/0.072
1000 Cycles	0.160/0.155	0.330/0.320	0.540/0.520
10000 Cycles	0.820/0.790	1.550/1.600	2.400/2.250
100000 Cycles	2.900/2.800	4.300/4.300	5.400/5.400

*Average of three sensors.

Read for Figures 54 and 55

TABLE 33 RANGE PAIR TYPE CYCLE COUNT

Alt. με	Theor* Input	Low Severity Flt												Theor* Input	High Severity Flt				
		LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ	LK	LL		HA	HB	HC	HD	HE
≥ 250		4	2	4	4	2	3	3	2	4	2	1	3		5	6	7	6	5
275								1	2	1					1		1	1	1
300			1					1			2	2				1	2		
325		1	2		2	1		1		1	2	1				2	1		
350			1	1		1	1	1	1			1	1		1		1	1	2
375		1		1											4			1	
400	12	8	7	7	7	8	8	6	7	7	7	6	8	15	11	11	11	11	13
425						1	1	1				1	1		2	1			
450	6	3	3	4	3	4	3	3	5	4	4	3	4	14	9	10	9	12	9
475							2		1			2	1			2		1	1
500	4	1	3	1	2	4	2	1	1	2	4	2	3	11	7	7	8	7	8
525								1							1	2		1	1
550	2	2	1	2	1	1	1	1	2	1	1	2	1	8	5	3	5	3	5
575			1	1				1	1				1		1			1	1
600	1	1		1	2		1					1		7	3	5	4	4	4
625										1		1			1		2	1	1
650			2				1	1		1				3	2	1	1	1	2
675								1	1								1	1	
700		1			1	1			1		1	1	1	1				1	1
725					1			1		1								1	1
750		1					1							1					
775				1											2			1	
800		1		1						1	1				1	1			
825			2		1												1		
850						1		1							1	2	1		1
875																1			
900		1					1		1			1			1	2			
925															1	1		1	
950				1	1	1				1	1		1						
975																	1		1
1000																		2	
1025																	1		1
1050																	2		
1075																			
1100																1	1	1	
1125																			
1150																			
1175																1		1	1
1200																			1
1225															1				
1250																			
TOTALS	25	25	25	25	25	25	25	25	25	25	25	25	25	60	60	60	60	60	60

*See Section 2.4.5

TABLE 34 RANGE PAIR TYPE CYCLE COUNT

Alt. µε	Theor* Input	Low Severity Flt												Theor* Input	High Severity Flt				
		LM	LN	LO	LP	LQ	LR	LS	LT	LU	LV	LW	LX		HF	HC	HH	HI	HJ
≥ 250		9	4	3	3	3	5	7	3	4	3	3	2		9	7	6	5	8
275								1	1			2				1	1	1	
300				1		1			1	1			1				2	3	2
325						1					1	1	1		1	2			
350			1	1								1					1	1	
375		1		1			1									1	2	1	1
400	12	8	8	6	8	7	6	7	7	6	9	6	9	15	11	10	11	10	11
425			1		2		1			1						1	1	2	
450	6	3	3	5	5	6	5	6	5	5	3	3	4	14	9	9	10	10	9
475						1					1				1	1		1	
500	4	1	2	2	2	1	1	1	2	2	2	2	3	11	8	7	7	6	8
525						1	1			1									2
550	2	1	1	1	1	1	2	1	1	1	2	1	2	8	8	4	3	5	3
575			1							1			1			1	3	1	
600	1			1	1				1		1	1		7	3	5	4	4	4
625					1		1	1			1	1					1	1	2
650		1		1					1	1				3	2	1	1	1	1
675												2				1			
700			1											1	2				1
725			1															1	
750														1				1	
775		1	1			1			1	1	1	1	1				1		
800				2				1										1	1
825					1		1		1						1	2			1
850						1					1		1			1	2		1
875															1	1			1
900					1				1			1			2	1	1		
925																1		1	
950			1	1		1	1			1									1
975																		1	1
1000																			
1025															1		1	1	
1050																			
1075																1			1
1100																1			
1125															1			1	
1150																	1		
1175																			
1200																1			
1225																	1	1	1
1250																			
TOTALS	25	25	25	25	25	25	25	25	25	25	25	25	25	60	60	60	60	60	60

*See Section 2.4.5

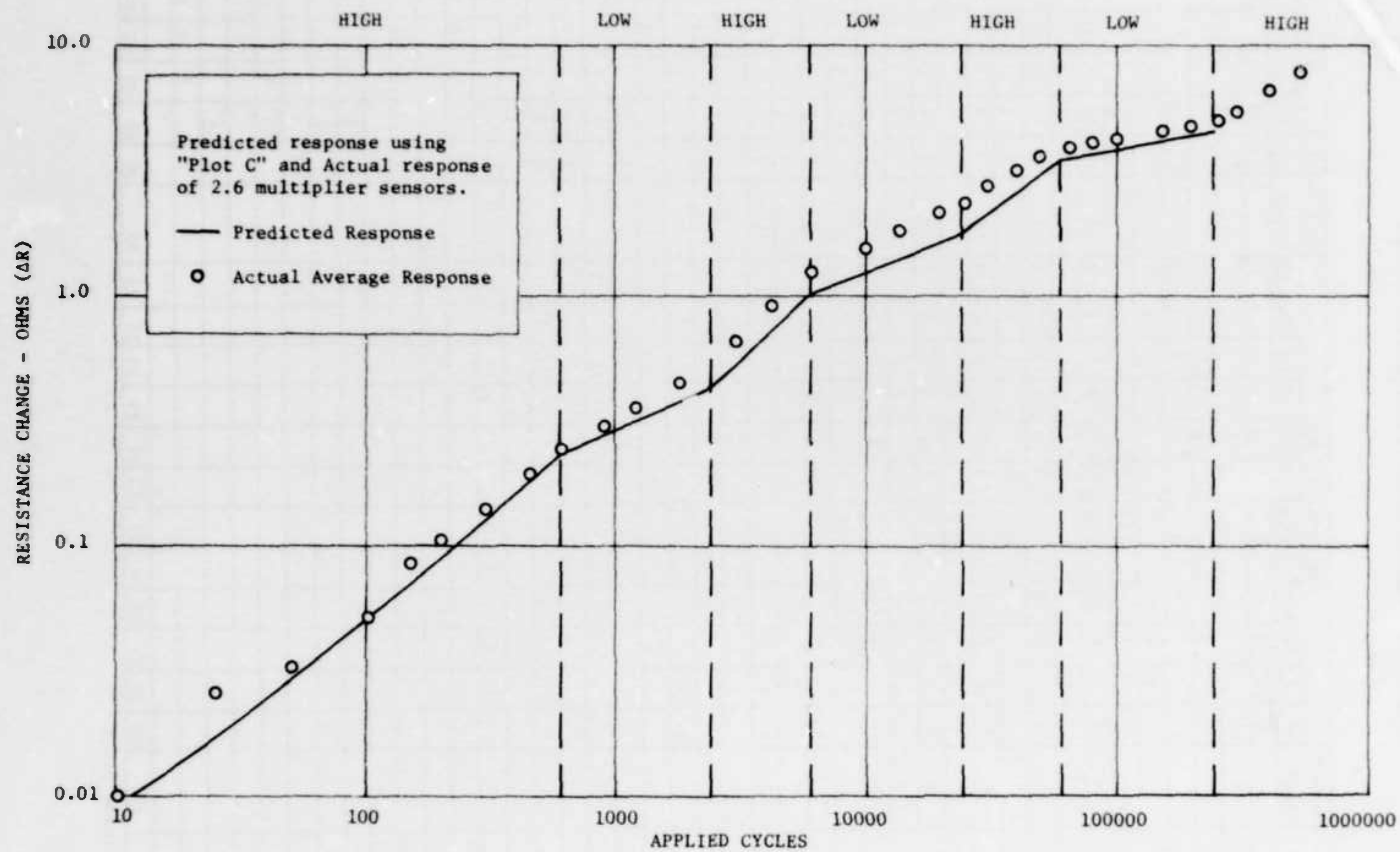

Figure 56 Spectrum Test Actual Fatigue Sensor Response Versus Prediction, Specimen #24

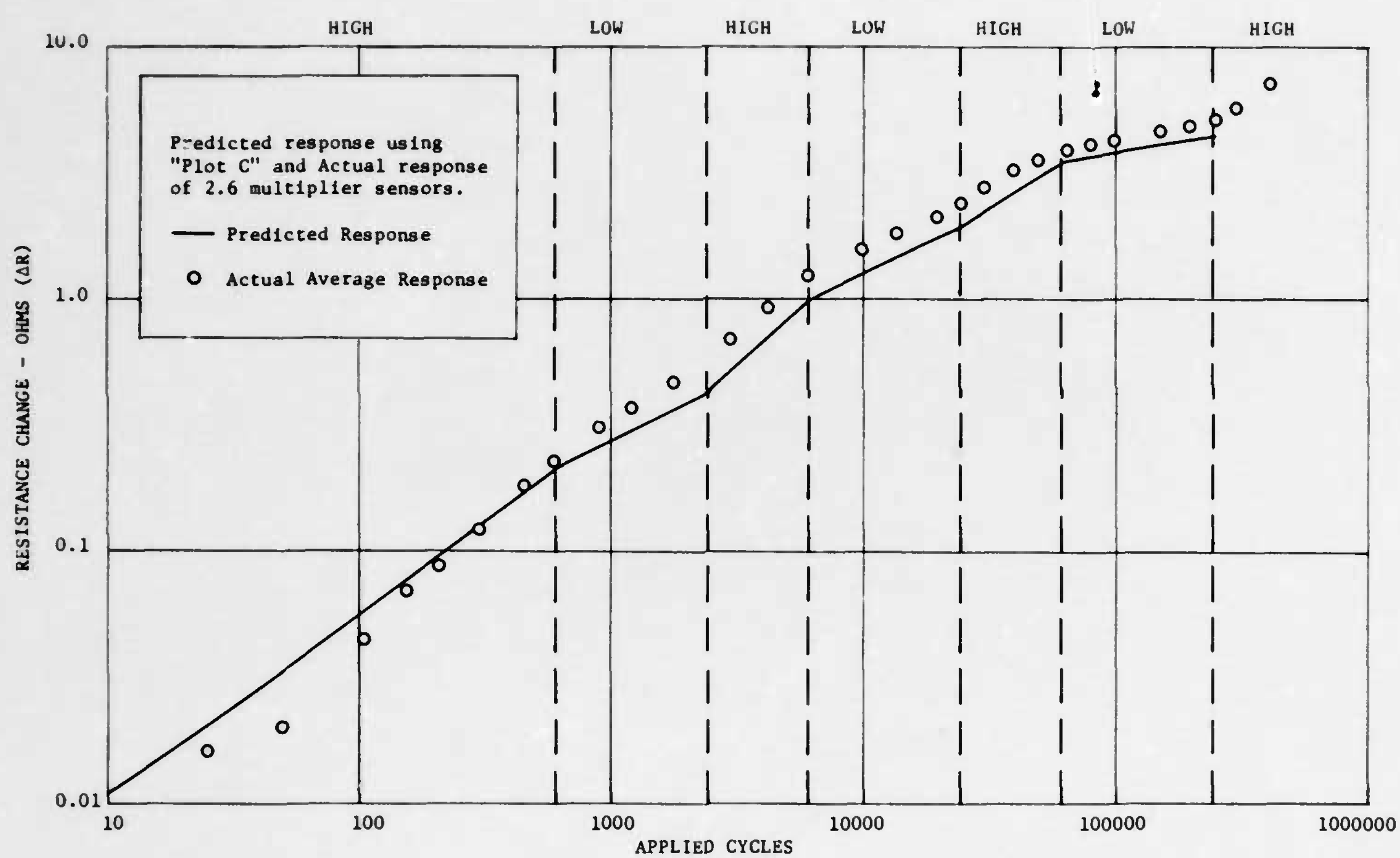

Figure 57 Spectrum Test Actual Fatigue Sensor Response Versus Prediction, Specimen #25

SECTION VI

TEMPERATURE RESPONSE

6.1 AMBIENT TEMPERATURE VARIATION

Test data from specimen #26 were analyzed to develop correction rates for ambient temperature variations during the life of the FM fatigue sensor. Test data were collected and are analyzed for four different FM multipliers from 0-6 ohms sensor life (ΔR). It should be noted that the fatigue sensors discussed in this section, as well as the rest of the test program, were bonded with M-16 adhesive. M-16 was subsequently shown to be subject to creep at elevated temperature (see Sec. 7.7). It seems probable that some discrepancy exists in the results of this section due to this phenominon.

6.1.1 Data Analysis

Resistance change (ΔR) due to temperature (data and development plots from Sect. 6.4) was plotted for each multiplier at seven points in sensor life. A curve fit was drawn through each set of data plotted as shown by examples of Figure 62 thru 65. Ambient temperature response was found to be approximately linear from 0-120°F; a straight line curve fit was used for this portion of the curve (hot data tended to deviate slightly from straight line, possibly due to high temperature creep, see section 7.7). The slope of the straight line was used to form a temperature correction rate (ohms/°F, useful range = 0-120°F).

Figures 66 thru 70 show the family of curves developed for each multiplier using the curve fits of test data (data were adjusted for zero at 75°F).

The temperature correction rates (slopes of straight lines) were plotted versus fatigue sensor life as shown by Figure 50. The data from this plot is the basis of temperature correction for fatigue sensor data using the following equation:

$$TKCR = \Delta T\ (TK + (\text{slope})\ (\Delta R))$$

Where: TKCR = Temperature correction to be added to fatigue sensor measured resistance change (ΔR).

ΔT = Temperature change from initial zero reading (°F)

TK = Zero ohm correction rate (negative of intercept shown by Figure 58)

Slope = Rate of change of correction versus sensor life (Figure 58)

ΔR = Uncorrected resistance change

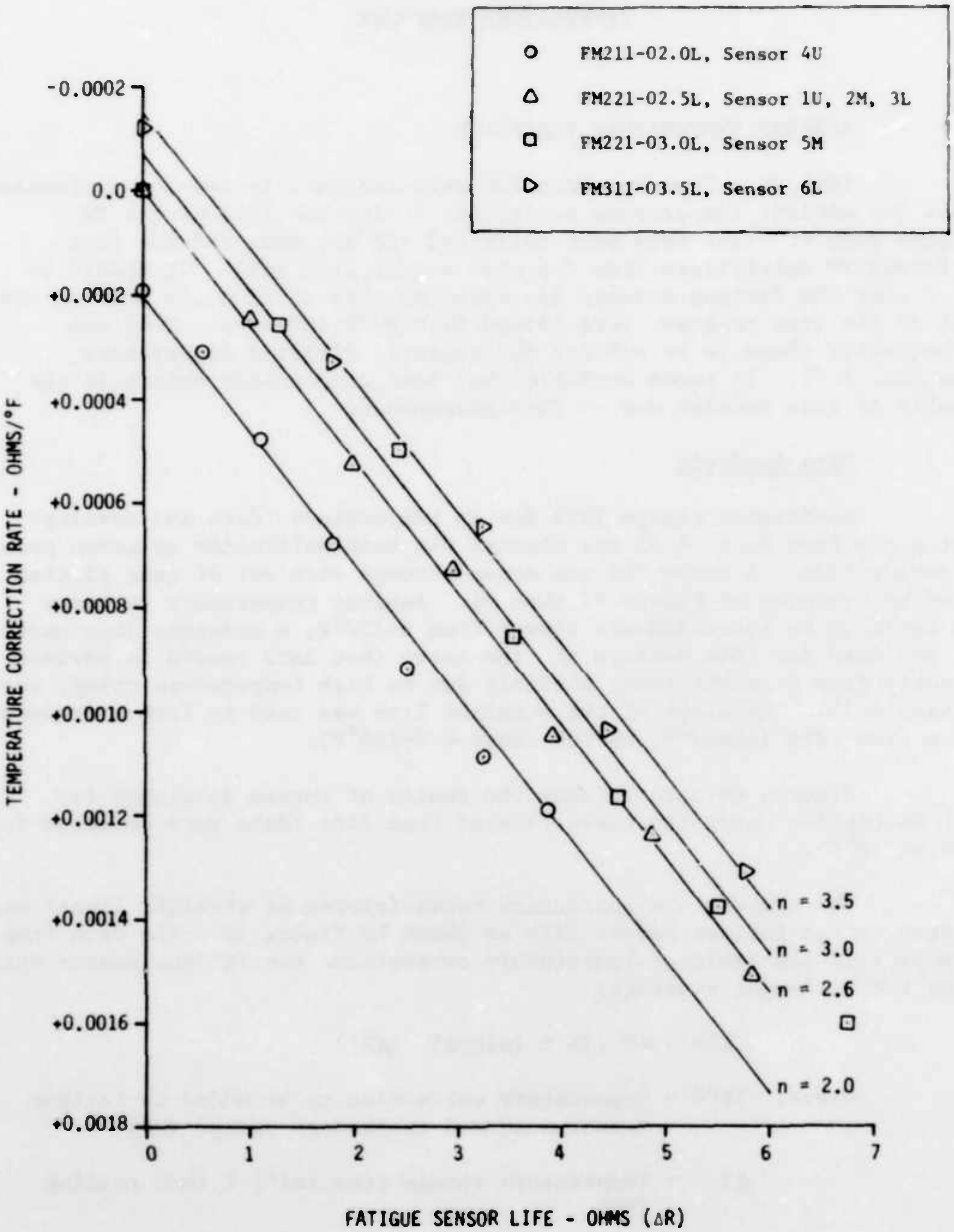

Figure 58 Ambient Temperature Correction Rate Versus Sensor Life (0-120°F)

TABLE 35 TEMPERATURE CORRECTION CONSTANTS FOR TEMPERATURE CORRECTION EQUATION

NOTES: 1) Correction rates are applicable for ambient temperatures from 0 to 120 ^{o}F.

2) Slope and intercept developed from plot of correction rate versus sensor life (see Figure 58).

Preliminary Correction Rates*		
Mult.	TK (Intercept)	Slope
2.0	0.00035	0.00023
2.6	0.00024	0.00023
3.0	0.00013	0.00023
3.5	0.00007	0.00023

*Used for constant amplitude and spectrum loaded test data analysis of this report.

Final Correction Rates**		
Mult.	TK (Intercept)	Slope
1.0	0.0	0.0
2.0	0.00021	0.00025
2.6	0.0	0.00025
3.0	-0.00007	0.00025
3.5	-0.00015	0.00025

**Derived from Figure 58

The test data which have been corrected for temperature variation (constant amplitude and spectrum loaded tests, (see Table F-2 for example) used the foregoing temperature correction method. However, correction rates were based on preliminary plots of temperture data which differed slightly from the final rates developed by Figure 58. Table 35 shows both preliminary and final temperature correction rates.

6.1.2 Results

Usable temperature correction rates for ambient temperature variations were developed from test data. These rates were found to be quite small with a characteristic of increasing with increasing fatigue sensor life (resistance change). As a result, any inaccuracy due to creep under load (see sect. 6.2.2 and 7.7) would have had a disproportionately large effect on the established temperature correction rates. However, temperature corrections will, in general, be a small percentage of total resistance change. In practical terms, the FM fatigue sensor is temperature compensated for many applications.

6.2 STRAIN CYCLES WITH VARYING TEMPERATURE

Four specimens (#27 thru #30) were cycled at different operating ambient temperatures under identical constant amplitude strain cycles. Test data were analyzed to establish the operational temperature range of the FM sensor.

6.2.1 Data Analyses

Test data from each specimen (Tables 39 thru 42) was plotted and compared to predicted response for room temperature operation (Note: Predicted response is for ±1000 alternating, +1000 mean strain, see Section IV). Figures 75 thru 78 show plotted data. Data plots indicated normal FM fatigue sensor response for operation at $+150^{\circ}$ and $0^{\circ}F$, however response was low at $-60^{\circ}F$.

An examination of static load cycle data analyses (sample of load cycle analysis Table F-4) for these specimens revealed the following additonal information:

a) Although the $150^{\circ}F$ specimen indicated normal response during cycling (2cps), the effective multiplication was found to deteriorate during static load cycles. Test data indicated the FM multiplier assembly was experiencing a creep or slippage at $150^{\circ}F$ (see section 7.7).

b) At $-60^{\circ}F$ the effective strain multiplier deteriorated from 2.6 to 1.8 which agreed closely with the actual fatigue sensor response from cycling. A slight reduction in applied strain resulted from the increase of aluminum modulus of elasticity at $-60^{\circ}F$; this explained the unamplified sensors (3T, 4T[a]) giving slightly less response at $-60^{\circ}F$.

c) Normal multiplier behavior was exhibited at $0^{\circ}F$. A combination of specimen bending and strain cycle reduction (see b) above) resulted in reduced response for unamplified sensor 3T.

Upon completion of these test series, two specimens (#29 and #30) were subjected to a series of static load cycles at hot and cold temperatures. These tests are described as "hot" and "cold" multiplier tests by paragraph 2.2.8. Results of these tests were used to pin-point the temperature at which the FM multiplier began to deteriorate. Figure 59 plots these data with the limits of $+130^{\circ}F$ to $-20^{\circ}F$ established for FM fatigue sensor operation. The plot also shows the estimated dynamic response of the multiplier obtained by comparing predicted fatigue sensor response with actual response.

The static load cycle data also showed the effects of multiplier operation at extreme temperatures to be reversible. Normal multiplier function was restored by returning to the operating temperature range ($+130$ to $-20^{\circ}F$).

6.2.2 Results

a) The FM fatigue sensor was found to have a limited operating temperature range due to deterioration of multiplier performance at hot and cold temperature extremes.

b) Unamplified fatigue sensor operation indicated the fatigue sensor will perform over a wide temperature range (-60° to $+150^{\circ}F$) given constant multiplier performance.

c) The FM multiplier deterioration produced by extreme temperature was found to be reversible; i.e. normal operation was restored by returning to the normal operation temperature range ($+130$ to $-20^{\circ}F$).

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[a] 3T, 4T - See Figure 18

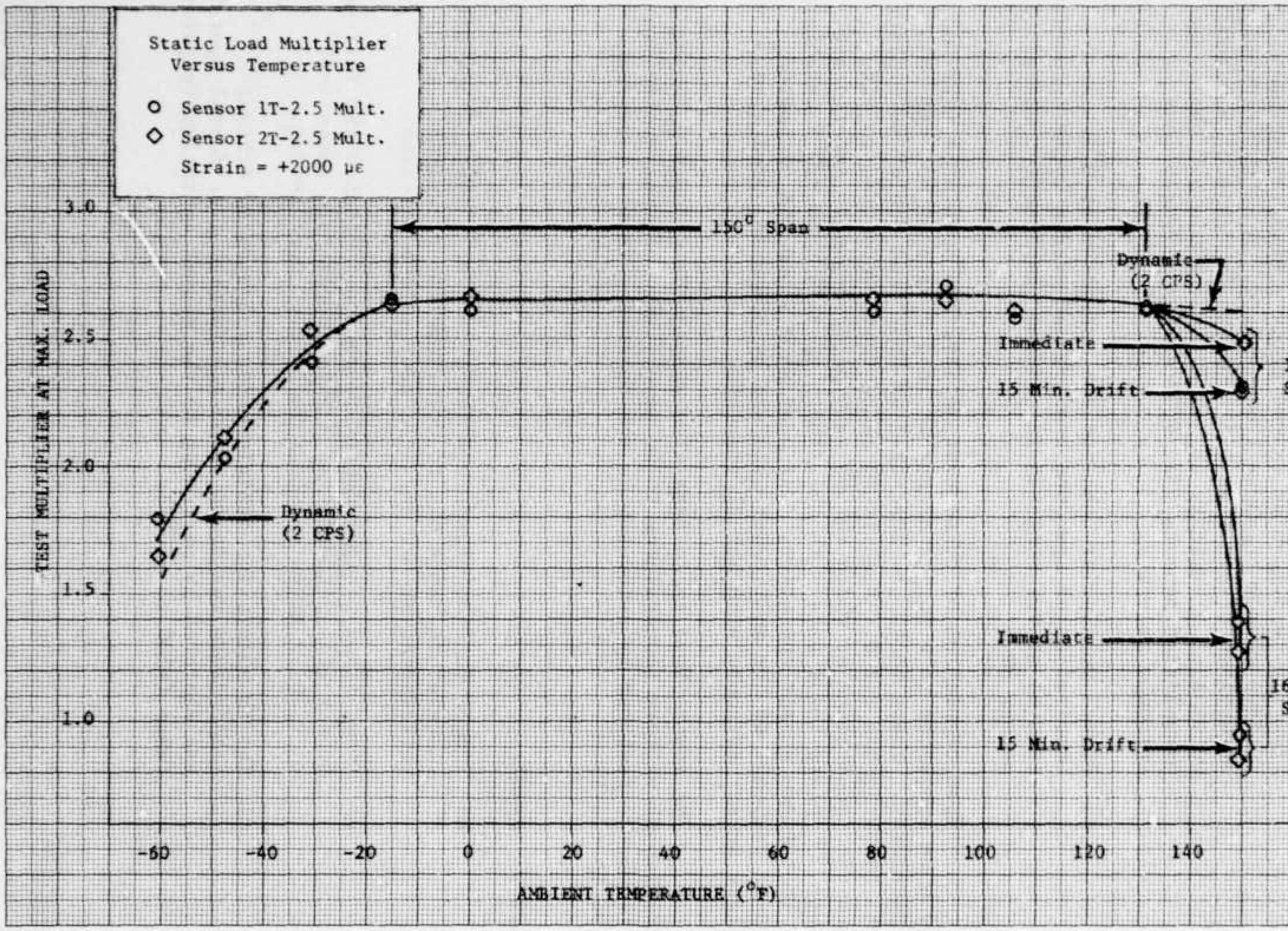

Figure 59 Operational Temperature Range

6.3 TEMPERATURE CYCLE STABILITY

Specimens #31 and #32 were subjected to 50 temperature cycles (+150 to -50°F) with no mechanical strain applied. These data were collected and analyzed to evaluate possible fatigue sensor response to apparent strain cycles induced by temperature.

6.3.1 Data Analysis

Fatigue sensor response for specimens #31 and #32 (Table 43 was plotted versus applied temperature cycles. Figures 60 and 61 present these data. As indicated, fatigue sensors remained stable within ±0.01 ohm; no resistance change pattern was observed.

The apparent strain cycle induced on fatigue sensors by the temperature cycle was measured five times during this test. Table 36 presents average alternating apparent strains calcualted by Tables 44 thru 48. The apparent strain cycle was analyzed in an attempt to provide rationale for the absence of fatigue sensor response to apparent strain cycles. This analysis is as follows:

a) The Micro-Measurements fatigue sensors are designed for effective temperature compensation when mounted on 9 PPM stainless steel material. Therefore, the expected mechanical strain cycle, when mounted on aluminum, is the difference in thermal expansion rates of aluminum (12.9 PPM) and stainless steel (9 PPM). For the 200°F temperature range used for the temperature cycle test, the expected strain cycle would be:

$$(12.9 - 9.0)\ (200^{\circ}F) = 780\ \mu\varepsilon \text{ or } 390\ \mu\varepsilon$$

b) From temperature cycle test data (Table 36), a ±400 $\mu\varepsilon$ apparent strain cycle was measured for umamplified FDA fatigue sensors on stainless steel. This apparent strain was larger than expected and is assumed to be produced by imperfection of temperature compensation over a wide temperature range. Therefore, the expected apparent strain cycle when FDA sensors were mounted on aluminum is:

Apparent stainless steel (measured)	= ±400 $\mu\varepsilon$
Additional mechanical strain when mounted on aluminum (calculated)	= <u>±390</u> $\mu\varepsilon$ ±790 $\mu\varepsilon$
Average actual apparent strain (measured) on aluminum	= ±725 $\mu\varepsilon$

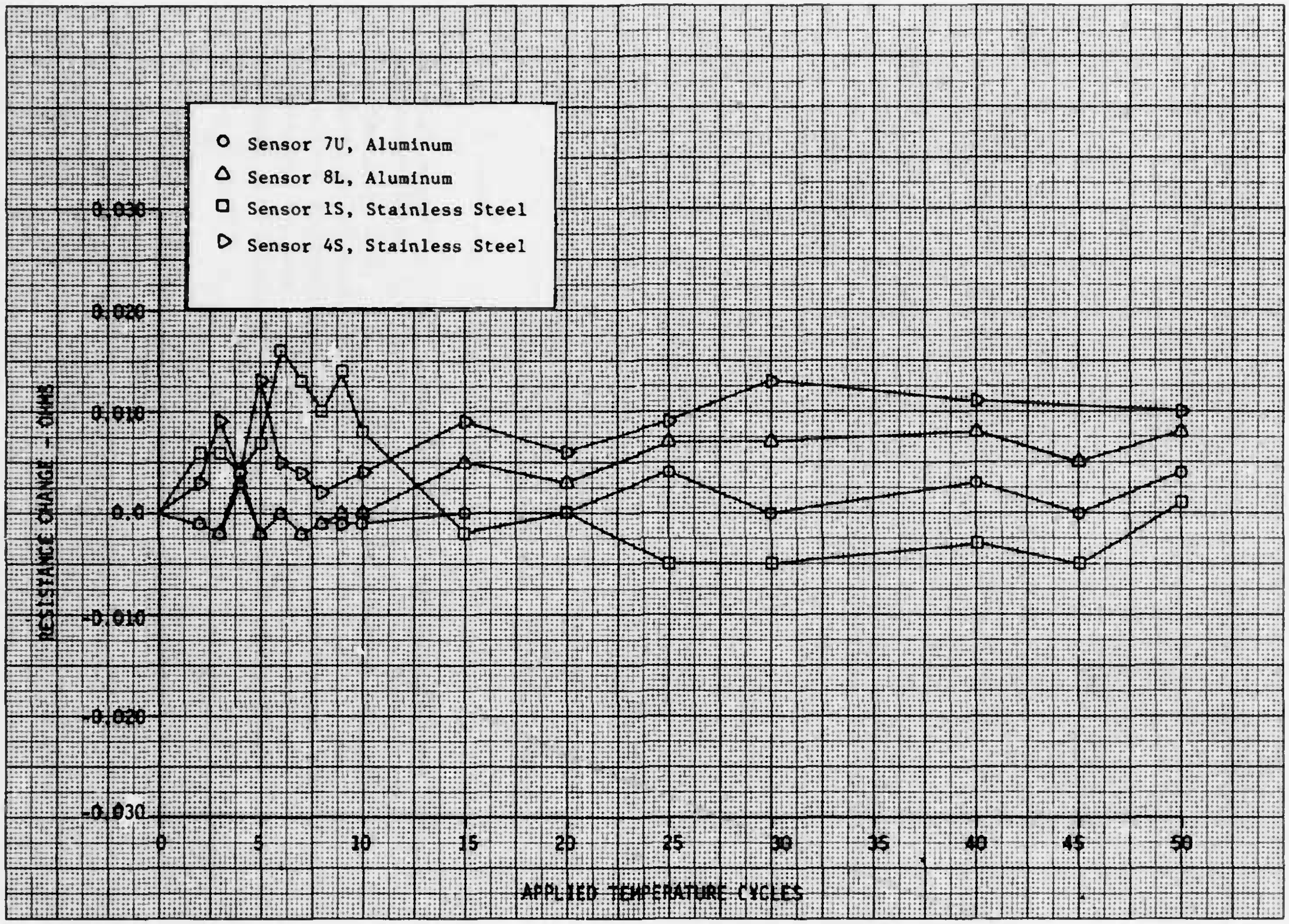

Figure 60 Temperature Cycle Stability Unamplified Fatigue Sensors

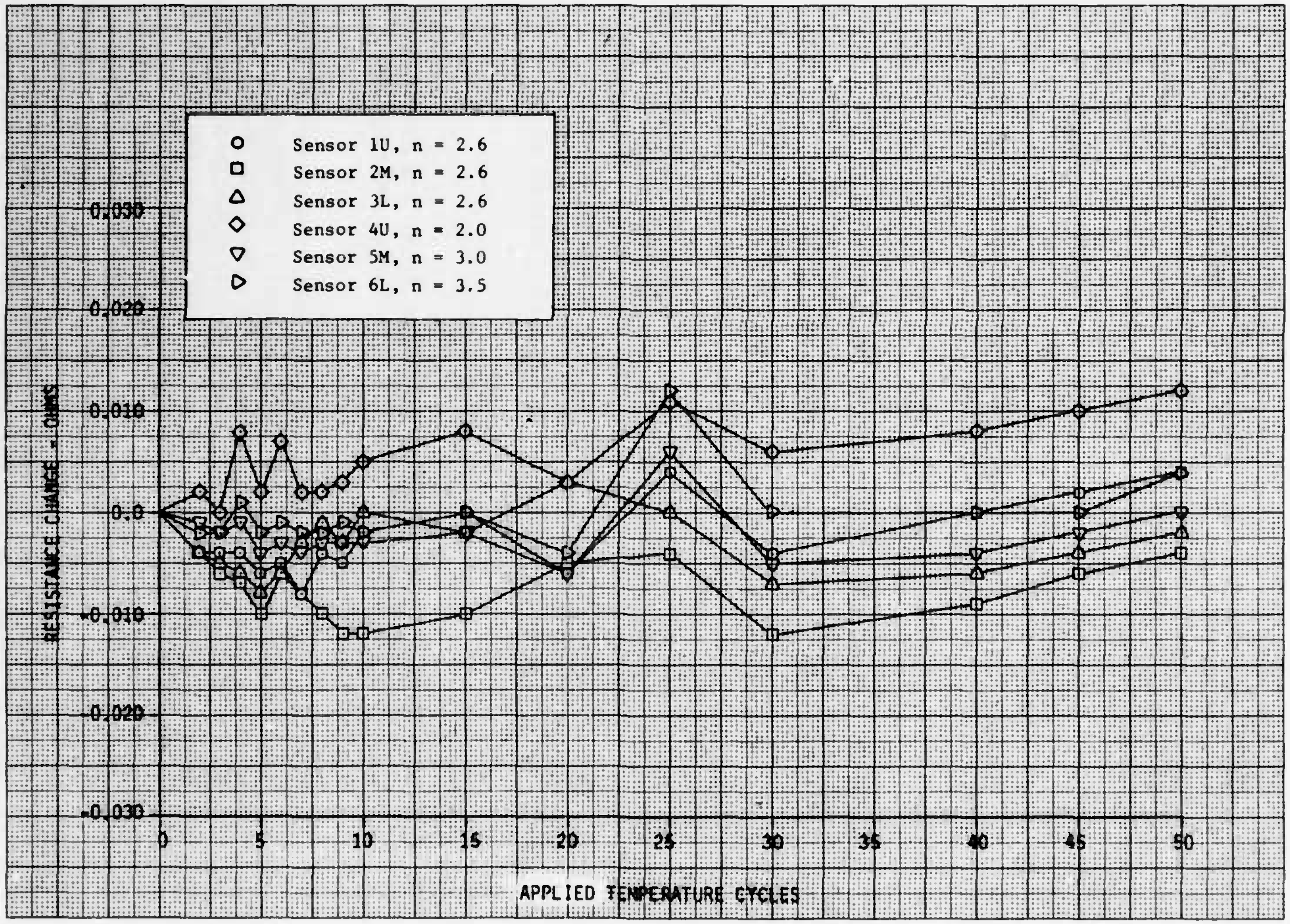

Figure 61 Temperature Cycle Stability FM Fatigue Sensors

c) For the amplified FM fatigue sensor, the average apparent strain (±1900 $\mu\varepsilon$) was approximately the same for each multiplier setting tested (2.0, 2.5, 3.0, 3.5). By comparing test data for amplified and unamplified fatigue sensors on aluminum, an effective multiplier factor for temperature induced apparent strain is calculated:

$$\frac{\text{Apparent amplified strain}}{\text{Apparent unamplified strain}} = \frac{1900}{725} = 2.62$$

d) The mechanical strain induced by mounting the amplified FM sensor on aluminum would be:

$$(\pm 390\ \mu\varepsilon)\ (2.62) = \pm 1021.8\ \mu\varepsilon$$

Table 36 summarizes the relationships developed by the foregoing apparent strain cycle analysis. The major unknown area of this analysis is the source of the ±400 $\mu\varepsilon$ apparent strain on stainless steel (is this apparent strain produced by thermal resistivity or thermal expansion), and the validity of multiplying this quantity by the apparent strain multiplier. Available test data did not provide adequate rationale to explain this quantity.

An additional unknown area of this test was the impact of high temperature creep on the apparent strain cycle. This creep or slippage of the FM multiplier was identified by the cyclic temperature test (see 6.2) and ambient temperature test (see 6.1). Test data indicates the creep would have a tendency to reduce the apparent strain cycle.

6.3.2 Results

a) Fatigue sensors mounted on stainless steel and aluminum were stable within ±0.01 ohm for 50 temperature cycles of +150 to -50°F.

b) The results of this test (no measurable resistance change) tend to support the idea that the amplified fatigue sensor was operating at or below threshold (±1000 $\mu\varepsilon$) in terms of applied mechanical strain. Apparently a significant portion of the measured apparent strain cycle was not induced by thermal expansion of the FM fatigue sensor/multiplier assembly. Analysis of apparent strain cycle data did not provide adequate rationale to identify the portion of the apparent strain produced by thermal expansion.

c) The FM fatigue sensor data is inconclusive due to the unknown effect of high temperature creep on the apparent strain cycle; i.e. the amount of reduction to the strain cycle due to slippage.

TABLE 36 SUMMARY OF APPARENT ALTERNATING STRAIN APPLIED BY 100° (+50° to +150° and + 50° to -50°F) TEMP CYCLES

APPLICATION	MEASURED APPARENT STRAIN FOR APPLICATION
a) Unamplified sensors on stainless steel (8.8 PPM)	= ±400 με
b) Unamplified sensors on aluminum (12.9 PPM)	= ±725 με
c) Amplified FM sensors on aluminum (12.9 PPM)	= ±1900 με

	Unamplified On Aluminum	Effective Apparent Strain Mult	Amplified On Aluminum
Apparent strain on stainless steel (assume to not be mech. strain) (measured)	±400	2.62	±1048
Expected temp. induced mech. strain between aluminum and steel (calculated)	±390	2.62	±1022
Total calculated apparent strain	±790	2.62	±2070
Apparent strain (measured) on test	±725	2.62	±1900

6.4 TEMPERATURE RESPONSE SUPPORTING DATA

TABLE 37 RESISTANCE CHANGE INTERVAL, SPECIMEN #26
(AMBIENT TEMP. CYCLE TEST)

SPECIMEN NO. = 26

ALT STRAIN = 1000 MEAN STRAIN = 0 ZERO TEMP = 76.0

INTIAL ZERO READING	1U	2M	3L	4U
	-0.864	-0.365	-0.211	-0.547

CALCULATED VALUES OF DELTA R

READ	CYCLES		TEMP	1U	2M	3L	4U
1	0.	A	76.0	0.0	0.0	0.0	0.0
2	0.	B	73.0	0.019	0.033	0.007	0.005
3	0.	A	73.2	0.046	0.045	0.040	0.038
4	0.	B	70.6	0.030	0.030	0.017	0.024
5	675.	A	72.7	0.977	0.997	1.084	0.527
6	675.	B	79.2	0.964	0.984	1.066	0.520
7	675.	A	72.6	0.963	0.983	1.063	0.516
8	675.	B	77.5	0.944	0.981	1.039	0.526
9 *	675.	A	75.2	0.974	1.015	1.066	0.556
10	675.	B	73.7	0.977	1.008	1.078	0.549
11	2060.	A	75.3	1.949	1.959	2.127	1.118
12	2060.	B	75.4	1.938	1.941	2.115	1.107
13	4700.	A	78.0	2.898	2.878	3.138	1.808
14	4700.	B	75.6	2.889	2.868	3.127	1.797
15	9400.	A	73.4	3.860	3.809	4.110	2.528
16	9400.	B	74.8	3.832	3.780	4.079	2.503
17	17650.	A	73.6	4.741	4.815	5.034	3.246
18	17650.	B	73.5	4.705	4.773	4.981	3.208
19	33300.	A	75.5	5.519	6.104	5.845	3.856
20	33300.	B	75.5	5.490	6.073	5.820	3.838

NOTE— CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE
A READINGS TAKEN BEFORE TEMP CYCLE
B READINGS TAKEN AFTER TEMP CYCLE

* Approximate +0.030 ohm zero shift due to rework of data collection system

TABLE 37 RESISTANCE CHANGE INTERVAL, SPECIMEN #26
(AMBIENT TEMP. CYCLE TEST, CONCLUDED)

SPECIMEN NO. = 26

ALT STRAIN = 1000 MEAN STRAIN = 0 ZERO TEMP = 76.0

INTIAL ZERO READING	5M	6L	7L	8L
	-0.365	-0.244	0.361	0.193

CALCULATED VALUES OF DELTA R

READ	CYCLES		TEMP	5M	6L	7L	8L
1	0.	A	76.0	0.0	0.0	0.0	0.0
2	0.	B	73.0	0.006	0.006	-0.004	0.010
3	0.	A	73.2	0.033	0.038	0.032	0.037
4	0.	B	70.6	0.027	0.021	0.034	0.036
5	675.	A	72.7	1.298	1.807	0.045	0.046
6	675.	B	79.2	1.277	1.774	0.041	0.041
7	675.	A	72.6	1.274	1.773	0.044	0.042
8	675.	B	77.5	1.256	1.775	0.043	0.044
9*	675.	A	75.2	1.295	1.808	0.067	0.069
10	675.	B	73.7	1.289	1.803	0.065	0.066
11	2060.	A	75.3	2.463	3.255	0.073	0.073
12	2060.	B	75.4	2.441	3.228	0.073	0.071
13	4700.	A	78.0	3.565	4.451	0.083	0.080
14	4700.	B	75.6	3.546	4.433	0.080	0.076
15	9400.	A	73.4	4.541	5.735	0.094	0.090
16	9400.	B	74.8	4.505	5.718	0.094	0.090
17	17650.	A	73.6	5.516	7.527	0.106	0.099
18	17650.	B	73.5	5.467	7.723	0.106	0.097
19	33300.	A	75.5	6.748	0.0	0.122	0.109
20	33300.	B	75.5	6.713	0.0	0.118	0.105

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE
A READINGS TAKEN BEFORE TEMP CYCLE
B READINGS TAKEN AFTER TEMP CYCLE

* Approximate +0.030 ohm zero shift due to rework of data collection system

TABLE 38 RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION FOR SPECIMEN #26

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 1 NOM DELTA R = 0 ZERO TEMP = 74.7 APP STR CYC = 0.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	-0.845	-0.332	-0.204	-0.541	-0.358	-0.238	0.357	0.203

CALCULATED VALUES OF DELTA R *

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	74.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	-65.5	-0.049	-0.072	-0.056	-0.039	-0.057	-0.059	-0.059	-0.048
3	-38.3	-0.041	-0.058	-0.042	-0.019	-0.044	-0.044	-0.043	-0.035
4	-0.3	-0.025	-0.044	-0.030	-0.001	-0.030	-0.029	-0.019	-0.017
5	39.2	-0.026	-0.042	-0.024	-0.006	-0.030	-0.027	-0.012	-0.014
6	61.0	-0.028	-0.043	-0.024	-0.013	-0.033	-0.028	-0.009	-0.018
7	150.4	-0.041	-0.050	-0.031	-0.030	-0.032	-0.017	-0.007	-0.027
8	119.0	-0.030	-0.038	-0.023	-0.024	-0.019	-0.012	-0.002	-0.015
9	75.0	-0.019	-0.033	-0.007	-0.006	-0.007	-0.006	0.004	-0.010

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 2 NOM DELTA R = 0 ZERO TEMP = 70.6 APP STR CYC = 0.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	-0.833	-0.334	-0.193	-0.521	-0.337	-0.223	0.395	0.229

CALCULATED VALUES OF DELTA R *

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	70.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	-66.1	-0.052	-0.051	-0.051	-0.037	-0.045	-0.050	-0.064	-0.043
3	-41.1	-0.027	-0.027	-0.027	-0.007	-0.021	-0.025	-0.035	-0.018
4	0.9	-0.014	-0.012	-0.015	0.010	-0.007	-0.011	-0.013	-0.002
5	40.0	-0.016	-0.006	-0.007	-0.002	0.002	-0.007	-0.004	0.001
6	59.7	-0.013	-0.009	-0.007	-0.002	-0.004	-0.007	-0.002	0.001
7	75.2	-0.010	-0.008	-0.010	-0.006	-0.009	-0.008	-0.003	-0.002
8	150.5	-0.011	-0.016	0.0	-0.005	-0.016	0.038	-0.009	-0.012
9	119.6	-0.003	-0.007	0.003	-0.006	-0.009	0.013	-0.004	-0.004
10	73.2	0.015	0.014	0.022	0.013	0.006	0.017	-0.002	0.001

* This temperature cycle is calculated using reverse order of raw data; final reading is used for initial zero. This procedure is required due to high temperature creep problems (see temperature data discussion)

TABLE 38 RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION FOR SPECIMEN #26 (CONTINUED)

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 3 NOM OELTA R = 1 ZERO TEMP = 79.2 APP STR CYC = 675.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	0.099	0.618	0.854	-0.029	0.910	1.528	0.402	0.234

CALCULATEO VALUES OF OELTA R *

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	79.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	-65.8	-0.011	-0.012	-0.006	-0.013	0.004	0.021	-0.059	-0.038
3	-36.6	0.003	0.002	0.009	0.012	0.017	0.029	-0.032	-0.015
4	0.0	0.005	0.005	0.007	0.022	0.014	0.022	-0.011	0.001
5	21.0	-0.001	0.004	0.009	0.018	0.013	0.015	-0.003	0.005
6	40.5	-0.017	0.005	0.009	0.006	0.008	0.009	0.0	0.005
7	60.2	-0.005	-0.002	0.0	-0.002	0.0	-0.001	0.0	0.002
8	72.7	-0.008	-0.005	-0.006	-0.002	-0.006	-0.005	0.001	0.001
9	76.2	-0.003	-0.005	0.0	0.0	-0.006	-0.006	0.002	0.002
10	99.3	-0.011	-0.012	-0.008	-0.009	-0.014	-0.012	0.0	-0.004
11	148.8	-0.029	-0.030	-0.023	-0.017	-0.028	-0.022	0.0	-0.012
12	122.9	-0.014	-0.014	-0.006	-0.005	-0.005	0.011	0.004	-0.004
13	72.7	0.015	0.015	0.020	0.011	0.025	0.037	0.004	0.005

* Same note as cycle nos. 1 and 2.

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 4 NOM OELTA R = 1 ZERO TEMP = 72.6 APP STR CYC = 675.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	0.100	0.619	0.853	-0.029	0.911	1.531	0.405	0.235

CALCULATED VALUES OF OELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	72.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	59.2	0.001	0.010	0.006	-0.007	0.017	0.005	-0.002	0.003
3	20.0	0.006	0.011	0.009	0.019	0.016	0.018	-0.007	0.003
4	-38.8	0.001	0.002	0.007	0.009	0.016	0.027	-0.036	-0.018
5	-64.0	-0.011	-0.010	-0.005	-0.013	0.005	0.020	-0.061	-0.038
6	2.2	0.010	0.012	0.011	0.023	0.019	0.025	-0.013	0.001
7	42.0	-0.001	0.019	0.015	-0.009	0.028	0.014	-0.002	0.004
8	74.5	0.0	0.001	0.002	0.002	0.001	0.001	-0.001	0.001
9	101.9	-0.016	-0.015	-0.016	-0.009	-0.011	-0.007	-0.001	-0.001
10	77.5	-0.021	-0.004	-0.026	0.009	-0.021	-0.001	-0.001	0.002

TABLE 38 RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION FOR SPECIMEN #26 (CONTINUED)

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 5 NOM DELTA R = 1 ZERO TEMP = 75.2 APP STR CYC = 675.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	0.110	0.650	0.855	0.009	0.930	1.564	0.428	0.262

CALCULATED VALUES OF DELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	75.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	60.0	0.003	0.002	0.002	0.004	0.003	0.002	-0.002	0.0
3	20.7	0.004	0.003	0.006	0.017	0.011	0.015	-0.008	0.0
4	-38.2	0.002	0.0	0.005	0.010	0.015	0.026	-0.035	-0.018
5	-65.4	-0.015	-0.016	-0.011	-0.022	0.001	0.015	-0.062	-0.042
6	0.8	0.010	0.004	0.007	0.021	0.016	0.023	-0.014	-0.004
7	39.5	0.020	0.028	0.013	-0.007	0.018	0.017	-0.004	0.001
8	75.6	-0.004	-0.003	-0.003	-0.005	-0.002	-0.002	-0.002	-0.003
9	100.3	-0.017	-0.018	-0.015	-0.012	-0.015	-0.012	-0.003	-0.006
10	125.3	-0.017	-0.027	-0.011	-0.019	-0.023	-0.019	-0.004	-0.012
11	73.7	0.004	-0.006	0.013	-0.006	-0.005	-0.004	-0.002	-0.003

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 6 NOM DELTA R = 2 ZERO TEMP = 75.3 APP STR CYC = 2060.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	1.085	1.594	1.916	0.571	2.099	3.012	0.434	0.266

CALCULATED VALUES OF DELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	75.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	61.4	0.006	0.005	0.006	0.002	0.006	0.006	-0.001	0.001
3	21.1	0.018	0.017	0.021	0.025	0.026	0.032	-0.005	0.002
4	-38.1	0.029	0.026	0.036	0.026	0.046	0.066	-0.034	-0.016
5	-65.3	0.022	0.020	0.031	0.008	0.044	0.069	-0.060	-0.039
6	1.1	0.024	0.022	0.027	0.031	0.035	0.047	-0.013	-0.002
7	40.2	0.027	0.018	0.022	-0.001	0.026	0.022	0.0	0.003
8	74.6	0.008	0.004	0.003	0.002	0.007	0.002	0.003	0.003
9	100.6	-0.030	-0.031	-0.031	-0.017	-0.030	-0.031	-0.001	-0.004
10	126.1	-0.053	-0.056	-0.051	-0.031	-0.058	-0.062	-0.003	-0.011
11	75.4	-0.011	-0.018	-0.012	-0.011	-0.023	-0.028	0.0	-0.002

TABLE 38 RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION FOR SPECIMEN #26 (CONTINUED)

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 7 NOM DELTA R = 3 ZERO TEMP = 78.0 APP STR CYC = 4700.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	2.032	2.511	2.925	1.259	3.198	4.205	0.444	0.273

CALCULATED VALUES OF DELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	78.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	60.3	0.019	0.016	0.015	0.006	0.013	0.016	-0.001	0.001
3	22.2	0.043	0.038	0.046	0.040	0.049	0.058	-0.002	0.006
4	-36.9	0.067	0.066	0.079	0.052	0.090	0.114	-0.033	-0.016
5	-63.9	0.068	0.066	0.083	0.037	0.096	0.125	-0.061	-0.039
6	0.8	0.054	0.051	0.059	0.051	0.066	0.082	-0.010	0.001
7	41.0	0.048	0.033	0.046	0.019	0.039	0.044	-0.002	0.002
8	74.9	0.006	0.006	0.006	0.001	0.003	0.005	0.0	0.001
9	100.5	-0.021	-0.020	-0.021	-0.014	-0.023	-0.021	0.002	-0.001
10	125.1	-0.048	-0.047	-0.047	-0.031	-0.053	-0.051	0.0	-0.007
11	75.6	-0.007	-0.008	-0.009	-0.009	-0.017	-0.016	-0.003	-0.004

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 8 NOM DELTA R = 4 ZERO TEMP = 73.4 APP STR CYC = 9400.0

ZERO READ	1U	2M	3L	4U	5M	6L	7L	8L
	2.999	3.447	3.902	1.983	4.179	5.495	0.455	0.283

CALCULATED VALUES OF DELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	73.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	60.7	0.010	0.009	0.008	0.008	0.010	0.011	-0.001	0.001
3	21.9	0.044	0.042	0.045	0.043	0.052	0.067	-0.004	0.004
4	-39.4	0.087	0.083	0.095	0.066	0.107	0.131	-0.033	-0.017
5	-64.9	0.093	0.090	0.106	0.059	0.119	0.118	-0.059	-0.039
6	1.9	0.063	0.060	0.067	0.061	0.075	0.093	-0.007	0.003
7	39.7	0.033	0.029	0.032	0.029	0.034	0.053	-0.001	0.003
8	75.7	-0.013	-0.011	-0.017	-0.009	-0.015	0.001	0.004	0.004
9	100.5	-0.054	-0.052	-0.056	-0.040	-0.058	-0.040	0.001	-0.004
10	124.3	-0.082	-0.083	-0.088	-0.062	-0.091	-0.077	-0.001	-0.008
11	74.8	-0.030	-0.031	-0.033	-0.026	-0.037	-0.019	0.0	0.0

TABLE 38 RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION FOR SPECIMEN #26 (CONCLUDED)

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC 9 NOM DELTA R = 5 ZERO TEMP = 73.6 APP STR CYC = 17650.0

ZERO READ

1U	2M	3L	4U	5M	6L	7L	8L
3.880	4.453	4.826	2.702	5.155	7.287	0.467	0.292

CALCULATED VALUES OF DELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	73.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	61.1	0.010	0.010	0.010	0.008	0.009	0.016	0.0	0.0
3	22.1	0.054	0.054	0.055	0.050	0.065	0.175	0.0	0.006
4	-39.5	0.110	0.113	0.118	0.087	0.139	0.152	-0.029	-0.014
5	-64.7	0.120	0.127	0.131	0.086	0.151	-0.078	-0.055	-0.036
6	0.6	0.076	0.075	0.078	0.067	0.091	0.167	-0.008	0.0
7	40.2	0.042	0.046	0.046	0.028	0.047	0.133	0.0	0.004
8	73.7	0.004	0.003	-0.003	-0.007	-0.002	0.122	0.0	-0.001
9	98.8	-0.045	-0.049	-0.062	-0.042	-0.051	0.115	0.0	-0.004
10	123.1	-0.097	-0.103	-0.117	-0.082	-0.110	0.068	-0.002	-0.011
11	73.5	-0.036	-0.042	-0.053	-0.038	-0.049	0.197	0.0	-0.002

RESISTANCE CHANGE DUE TO AMBIENT TEMPERATURE VARIATION SPEC NO 26

TEMP CYC10 NOM DELTA R = 6 ZERO TEMP = 75.5 APP STR CYC = 33300.0

ZERO READ

1U	2M	3L	4U	5M	6L	7L	8L
4.656	5.740	5.635	3.310	6.384	0.0	0.483	0.302

CALCULATED VALUES OF DELTA R

READ	TEMP	1U	2M	3L	4U	5M	6L	7L	8L
1	75.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	61.2	0.022	0.021	0.025	0.018	0.022	0.0	0.0	0.002
3	19.5	0.070	0.070	0.077	0.066	0.083	0.0	-0.008	0.002
4	-40.1	0.140	0.144	0.153	0.112	0.169	0.0	-0.037	-0.018
5	-66.6	0.158	0.162	0.166	0.111	0.190	0.0	-0.068	-0.045
6	0.4	0.094	0.096	0.101	0.088	0.114	0.0	-0.012	0.0
7	40.0	0.052	0.056	0.065	0.038	0.062	0.0	-0.001	0.004
8	74.6	0.005	0.009	0.009	0.004	0.009	0.0	0.003	0.005
9	101.3	-0.049	-0.046	-0.049	-0.036	-0.047	0.0	-0.006	-0.008
10	125.7	-0.101	-0.102	-0.101	-0.070	-0.107	0.0	-0.007	-0.011
11	76.0	-0.029	-0.031	-0.025	-0.018	-0.035	0.0	-0.004	-0.004

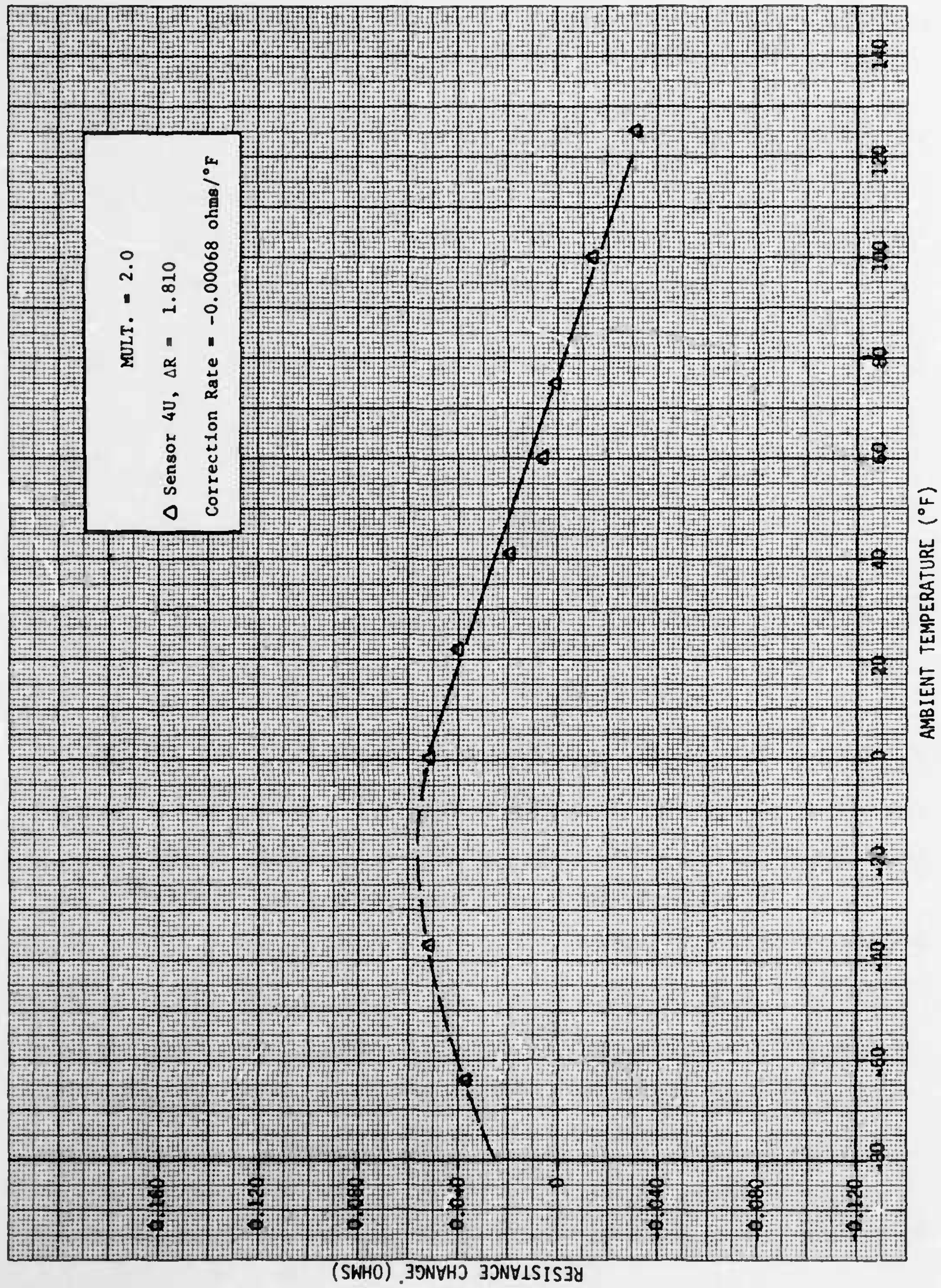

Figure 62 Ambient Temperature Response

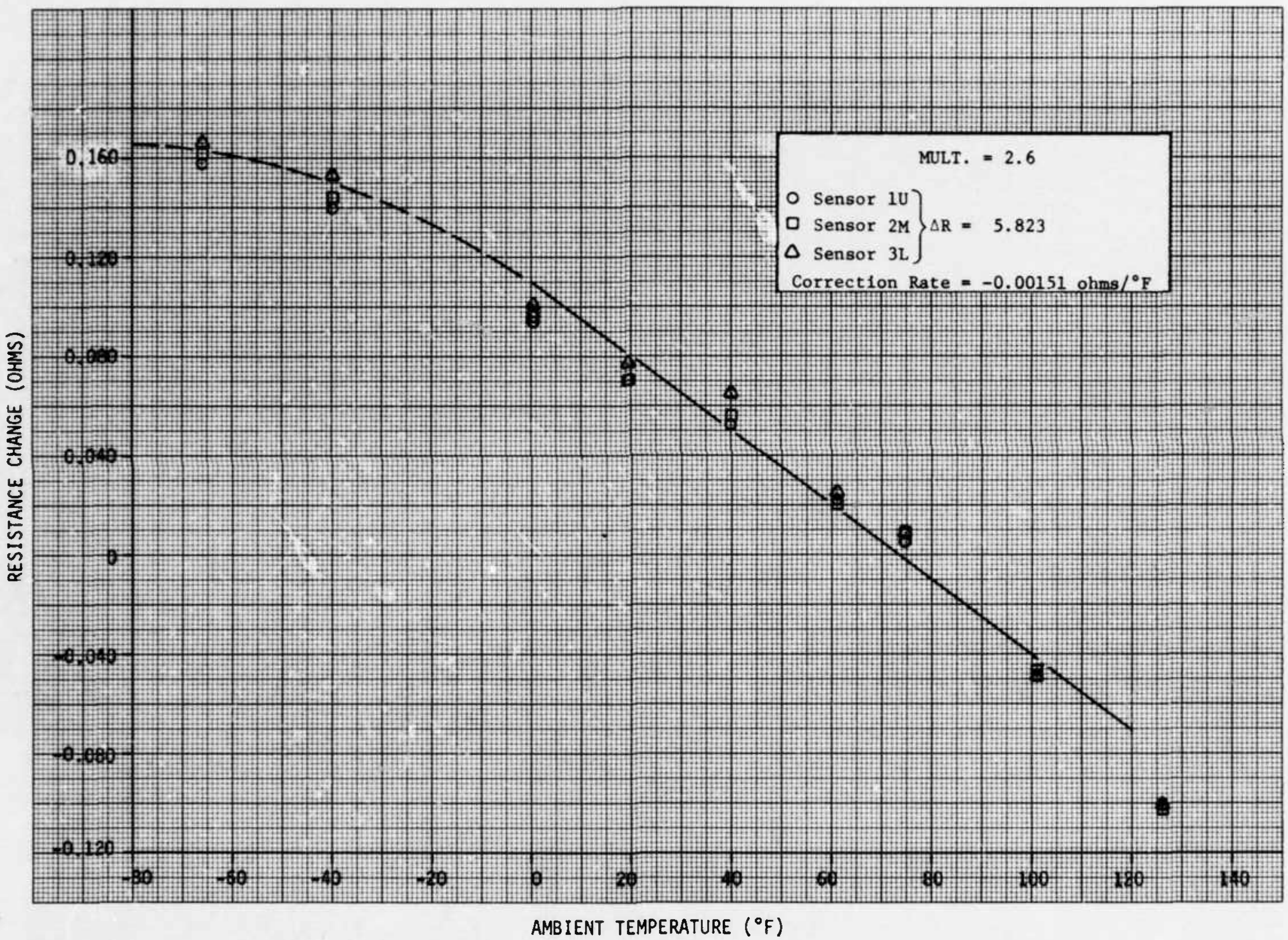

Figure 63 Ambient Temperature Response

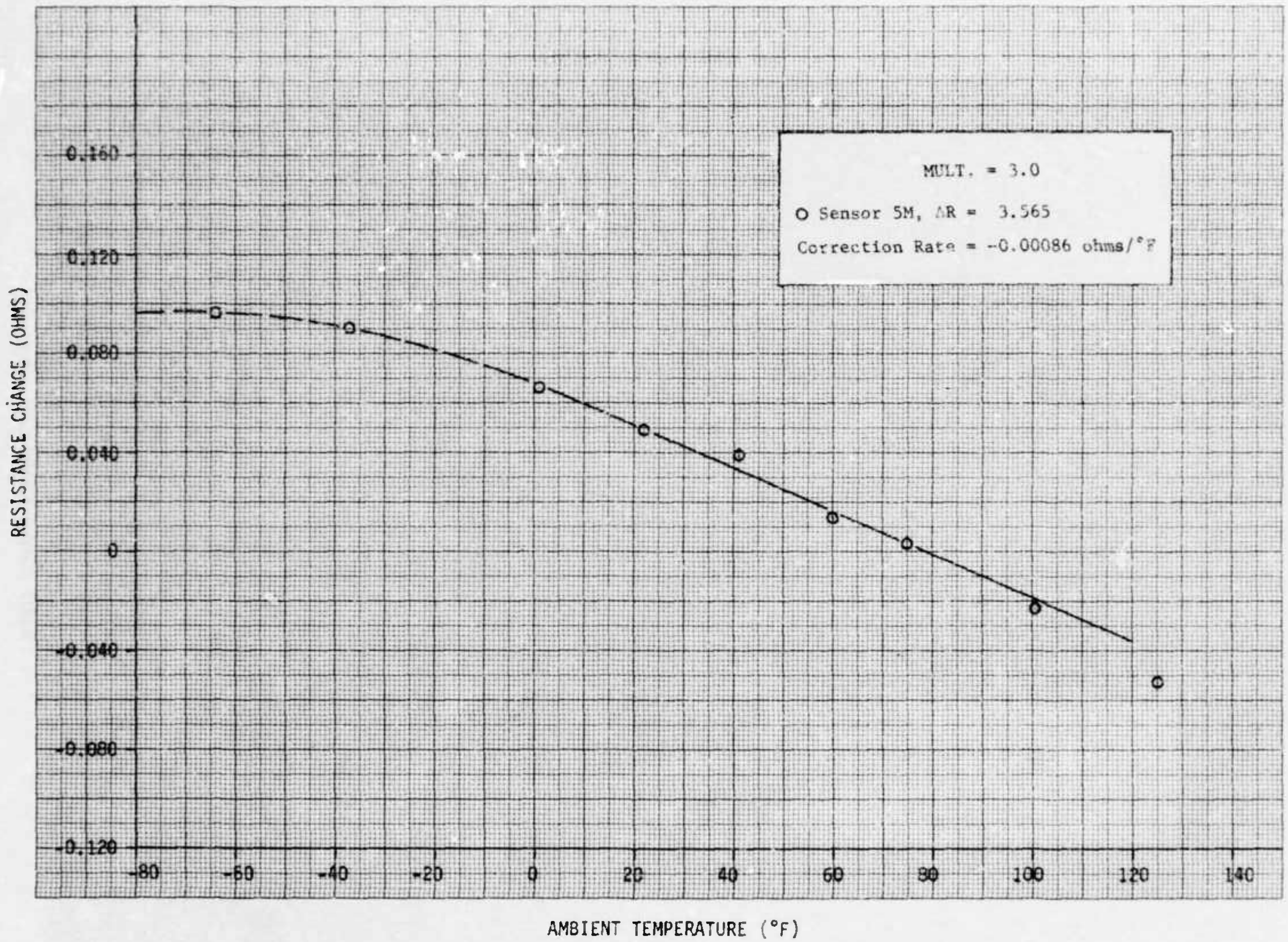

Figure 64 Ambient Temperature Response

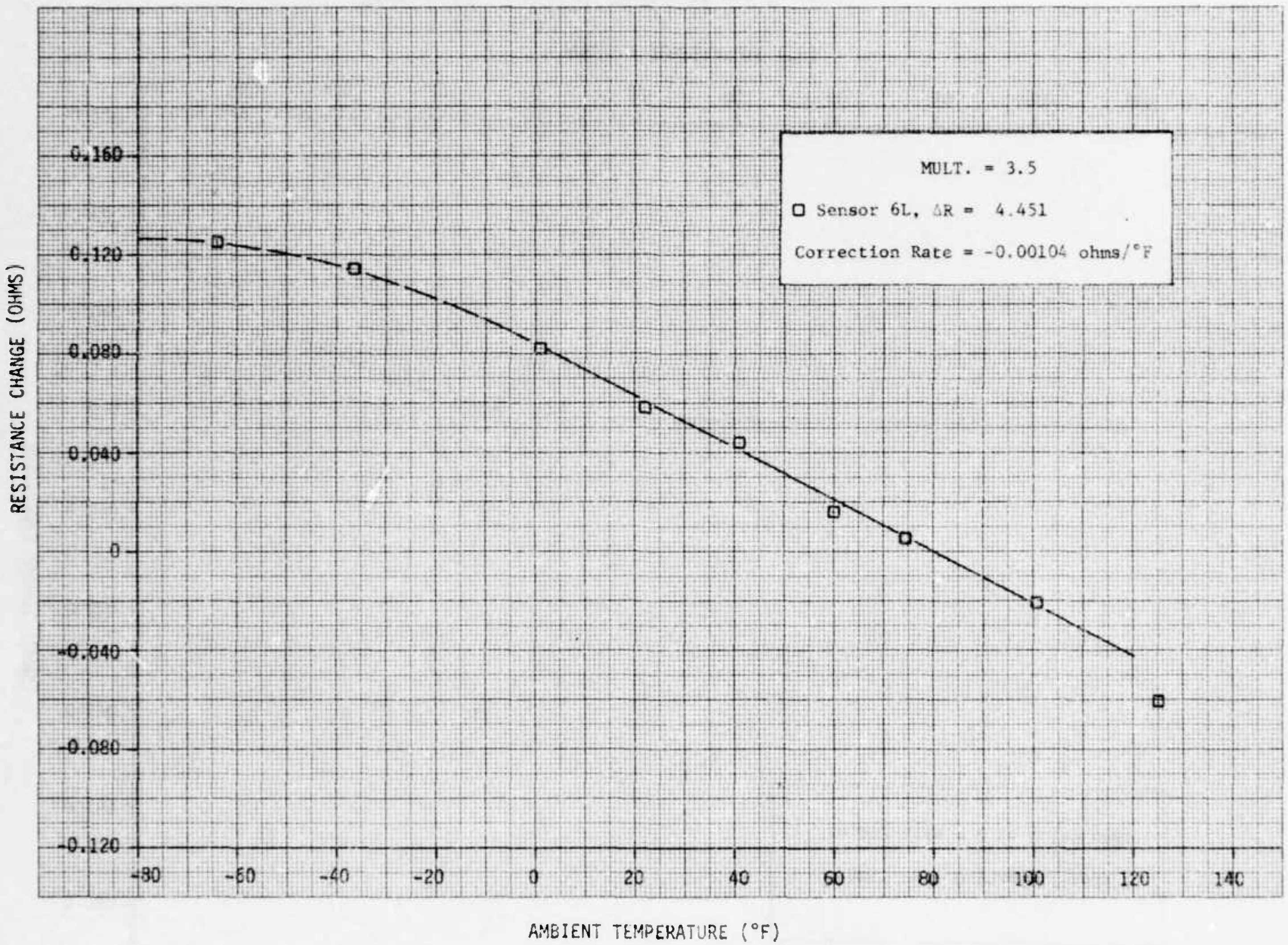

Figure 65 Ambient Temperature Response

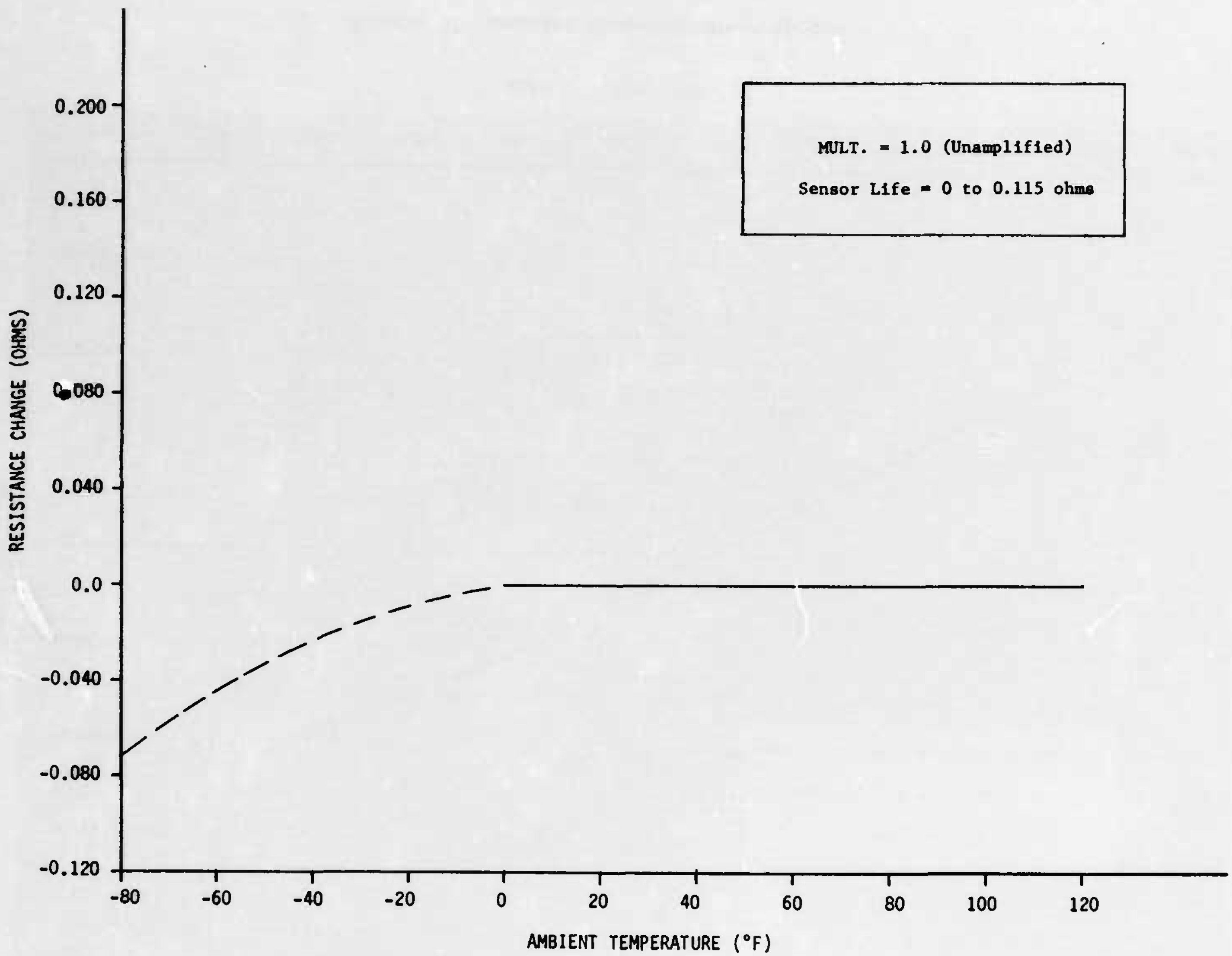

Figure 66 Ambient Temperature Response Versus Fatigue Sensor Life

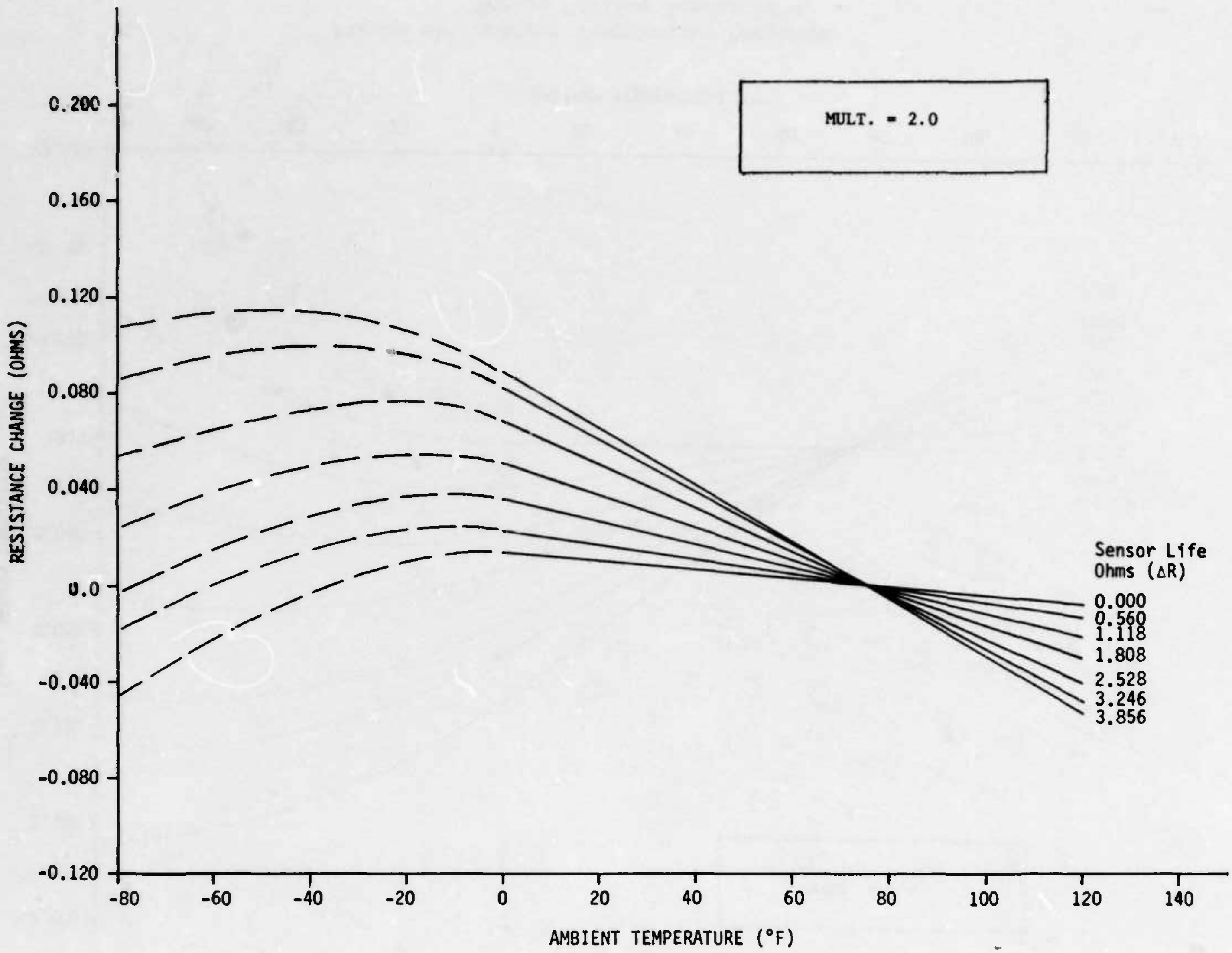

Figure 67 Ambient Temperature Response Versus Fatigue Sensor Life

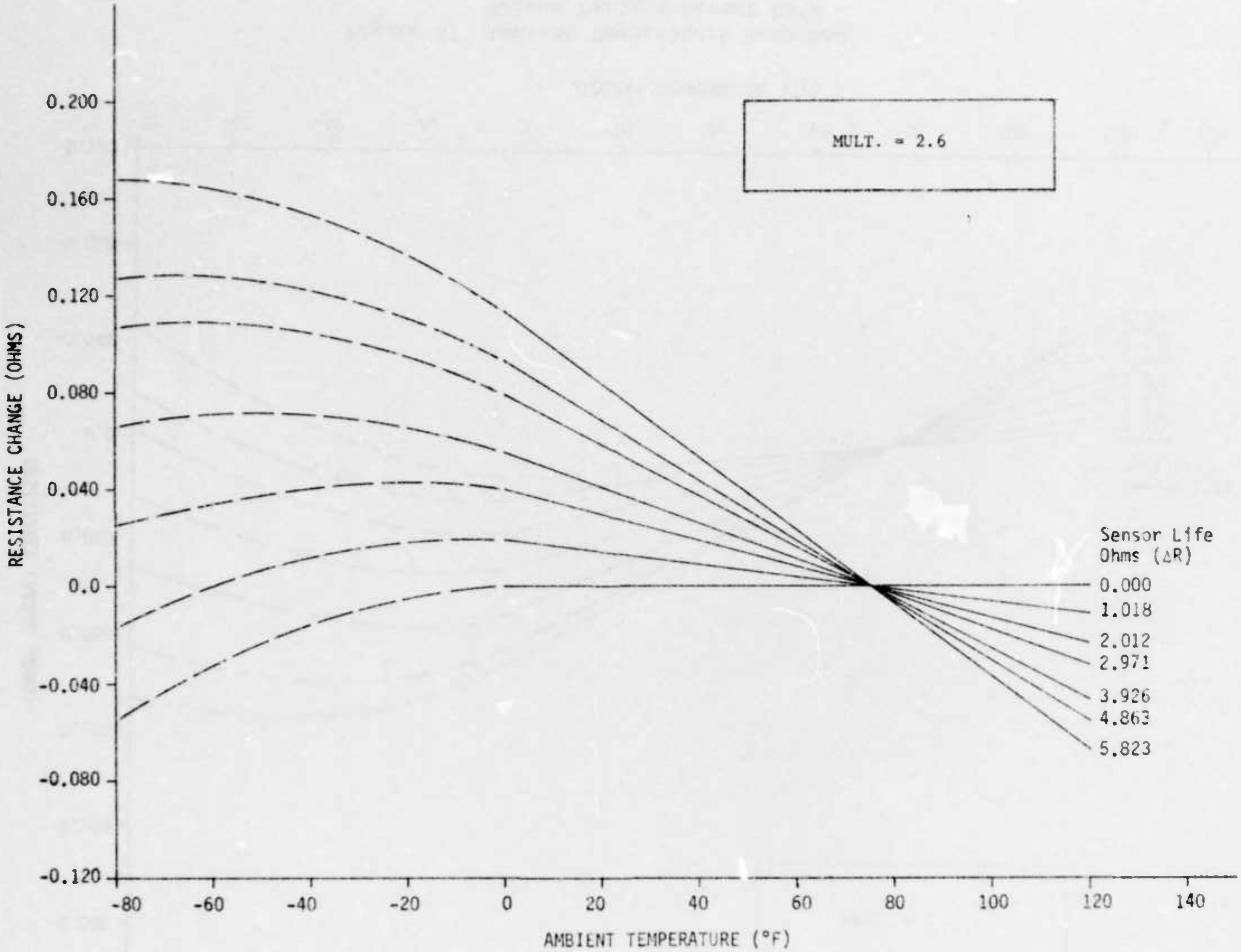

Figure 68 Ambient Temperature Response
Versus Fatigue Sensor Life

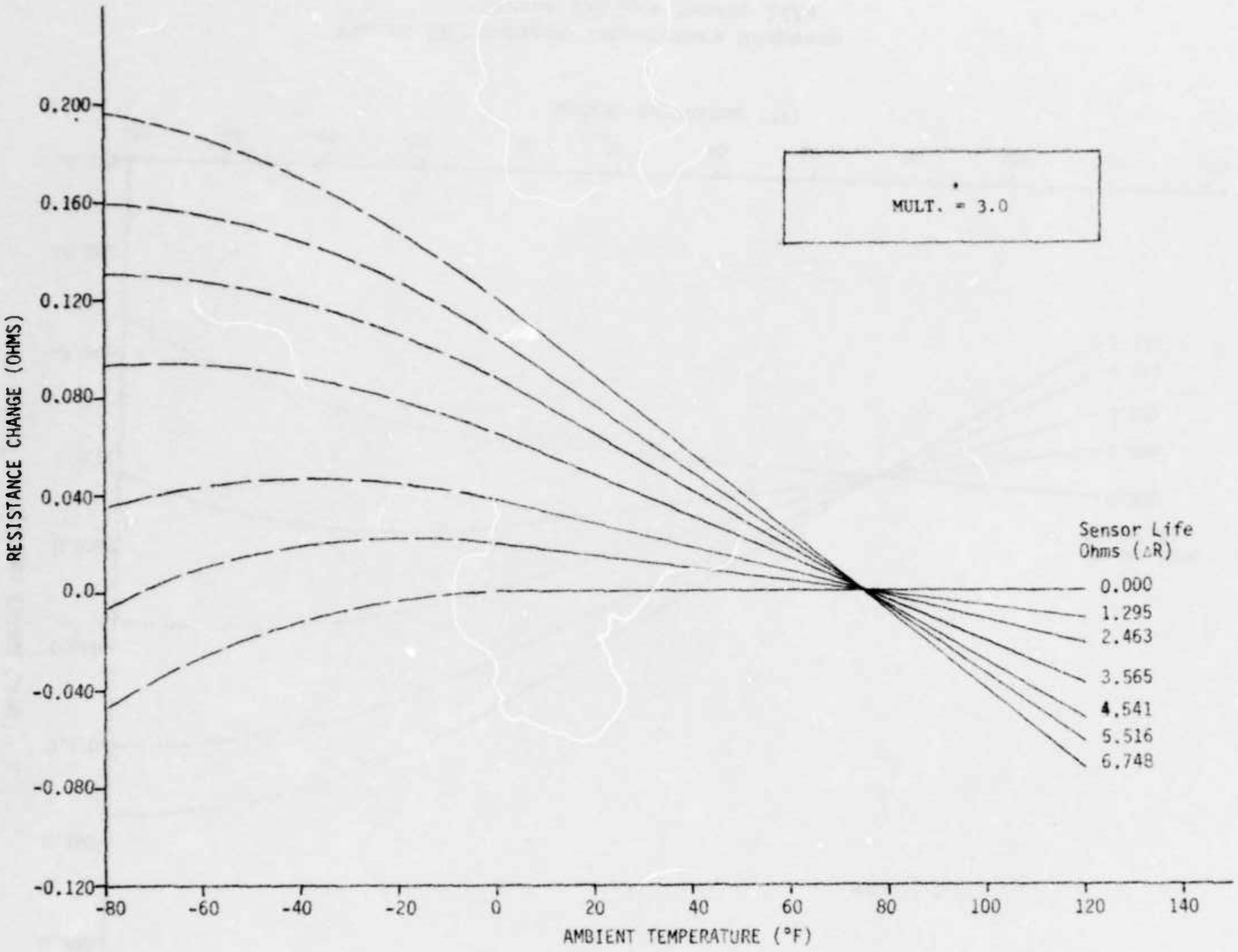

Figure 69 Ambient Temperature Response Versus Fatigue Sensor Life

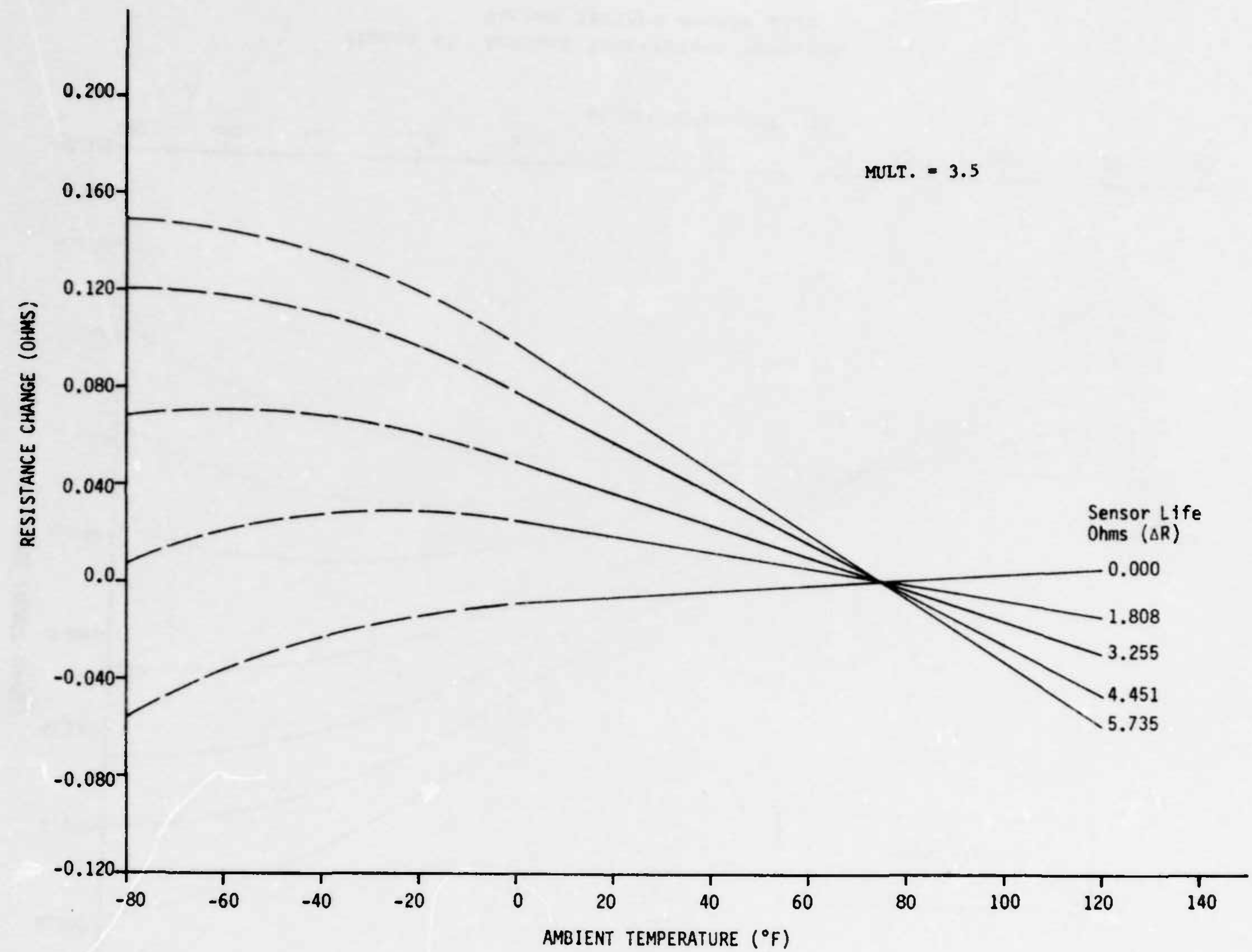

Figure 70 Ambient Temperature Response Versus Fatigue Sensor Life

TABLE 39 RESISTANCE CHANGE DATA FOR SPECIMEN #27

SPECIMEN NO. = 27

ALT STRAIN = 1000 MEAN STRAIN = 1000 NOM. TEMP = 80.0

INTIAL ZERO READING	1T	2T	3T	4T
	-0.304	-0.262	0.212	-0.149

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1T	2T	3T	4T
1.	10.	78.9	0.028	0.021	-0.008	-0.006
2.	25.	79.1	0.065	0.062	-0.006	-0.003
3.	50.	79.8	0.122	0.120	-0.007	0.0
3.	50.	77.7	0.110	0.110	-0.008	-0.001
4.	100.	79.5	0.206	0.210	-0.008	-0.002
5.	150.	80.2	0.290	0.292	-0.006	0.0
6.	200.	80.5	0.369	0.382	-0.006	0.0
7.	300.	80.5	0.512	0.524	-0.004	0.004
8.	500.	80.5	0.762	0.776	0.0	0.006
9.	700.	80.5	0.978	0.998	0.001	0.007
10.	1000.	80.9	1.254	1.272	0.002	0.011
11.	1500.	81.1	1.644	1.662	0.004	0.014
12.	2000.	81.1	1.966	1.980	0.008	0.021
13.	3000.	80.9	2.472	2.478	0.015	0.027
14.	5000.	80.9	3.170	3.154	0.028	0.041
15.	7000.	80.6	3.608	3.484	0.033	0.054
16.	9000.	80.6	3.937	3.900	0.045	0.063
16.	9000.	80.0	3.888	3.859	0.042	0.064
17.	10000.	82.1	3.984	3.988	0.043	0.061
18.	15000.	79.1	4.564	4.526	0.056	0.081
19.	20000.	79.2	4.982	4.884	0.074	0.094
20.	25000.	78.9	5.292	5.147	0.079	0.110
20.	29000.	78.1	5.532	5.319	0.088	0.114
21.	30000.	81.5	5.894	5.580	0.089	0.122
22.	40000.	80.2	6.381	5.990	0.107	0.140
23.	50000.	80.1	6.470	6.268	0.119	0.157
23.	56500.	79.8	6.315	6.396	0.121	0.160
23.	56500.	77.3	6.552	6.490	0.126	0.167
24.	65000.	77.2	0.0	7.380	0.132	0.175
25.	80000.	77.4	0.0	7.622	0.142	0.190
26.	89900.	77.7	0.0	0.0	0.146	0.197
26.	89900.	79.0	0.0	0.0	0.143	0.197
27.	100000.	79.0	0.0	0.0	0.148	0.203

TABLE 40 RESISTANCE CHANGE DATA FOR SPECIMEN #28

SPECIMEN NO. = 28

ALT STRAIN = 1000 MEAN STRAIN = 1000 NOM. TEMP =150.0

INTIAL ZERO READING

	1T	2T	3T	4T
	-0.745	-0.382	-0.195	-0.408

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1T	2T	3T	4T
1.	10.	149.0	0.033	0.039	-0.001	0.001
2.	25.	149.0	0.061	0.072	-0.005	0.003
3.	50.	149.4	0.107	0.134	-0.006	0.002
4.	100.	149.8	0.205	0.263	-0.005	0.0
5.	150.	149.8	0.275	0.352	-0.003	0.004
6.	200.	149.6	0.344	0.440	-0.003	0.004
7.	300.	149.7	0.467	0.597	-0.002	0.006
8.	500.	149.4	0.680	0.872	0.005	0.012
9.	700.	149.1	0.856	1.092	0.005	0.016
10.	1000.	149.5	1.087	1.378	0.003	0.014
11.	1500.	149.3	1.392	1.755	0.003	0.027
12.	2000.	149.6	1.635	2.044	0.015	0.022
13.	3000.	149.7	2.039	2.528	0.017	0.034
14.	5000.	149.1	2.595	3.176	0.017	0.042
15.	7000.	149.0	2.995	3.642	0.027	0.058
16.	9000.	149.3	3.283	4.006	0.025	0.058
17.	10000.	151.1	3.422	4.242	0.035	0.065
18.	15000.	150.9	3.971	5.033	0.041	0.083
19.	20000.	150.9	4.445	5.692	0.045	0.097
20.	25000.	151.1	4.874	6.546	0.052	0.110
21.	30000.	151.1	5.475	8.036	0.059	0.118
21.	35000.	150.6	6.061	8.836	0.061	0.126
21.	35000.	151.3	6.292	9.722	0.063	0.127
22.	40000.	150.4	7.559	0.0	0.065	0.134
23.	50000.	150.9	0.0	0.0	0.070	0.145
24.	65000.	151.0	0.0	0.0	0.084	0.166
25.	80000.	152.0	0.0	0.0	0.089	0.168
26.	100000.	150.1	0.0	0.0	0.098	0.183
26.	112500.	150.2	0.0	0.0	0.105	0.195
26.	112500.	78.8	0.0	0.0	0.114	0.201

TABLE 41 RESISTANCE CHANGE DATA FOR SPECIMEN #29

SPECIMEN NO. = 29

ALT STRAIN = 1000 MEAN STRAIN = 1000 NOM. TEMP =-60.0

INTIAL ZERO READING

	1T	2T	3T	4T
	-0.325	-0.434	-0.235	0.372

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1T	2T	3T	4T
1.	10.	-60.4	0.005	0.0	0.005	0.004
2.	25.	-60.4	0.013	0.006	0.004	0.005
3.	50.	-60.4	0.023	0.010	0.0	0.004
4.	100.	-60.9	0.037	0.019	-0.003	0.0
5.	150.	-60.9	0.051	0.026	0.003	-0.002
6.	200.	-60.6	0.063	0.037	0.004	-0.002
7.	300.	-60.9	0.085	0.048	0.019	0.018
8.	500.	-60.5	0.130	0.074	0.035	0.0
9.	700.	-60.5	0.166	0.092	0.0	-0.002
10.	1000.	-61.0	0.225	0.131	0.009	0.008
11.	1500.	-60.6	0.301	0.174	0.009	0.013
12.	2000.	-61.5	0.372	0.215	0.013	0.016
13.	3000.	-62.5	0.483	0.278	0.018	0.010
14.	5000.	-62.8	0.683	0.394	0.019	0.012
15.	7000.	-63.5	0.835	0.485	0.029	0.012
16.	9000.	-63.1	0.959	0.560	0.015	0.018
17.	10000.	-63.0	1.011	0.593	0.019	0.022
18.	15000.	-62.5	1.232	0.724	0.025	0.013
18.	16000.	-63.0	1.273	0.752	0.025	0.020
18.	16000.	-63.0	1.269	0.750	0.025	0.015
19.	20000.	-62.3	1.409	0.835	0.025	0.026
20.	25000.	-60.0	1.547	0.921	0.029	0.022
21.	30000.	-60.7	1.659	0.992	0.036	0.026
22.	40000.	-60.1	1.840	1.104	0.031	0.028
23.	50000.	-60.4	1.973	1.190	0.034	0.028
24.	65000.	-61.0	2.125	1.287	0.034	0.030
25.	80000.	-59.5	2.249	1.370	0.046	0.032
26.	100000.	-60.8	2.373	1.454	0.045	0.032
27.	100000.	79.0	2.275	1.412	0.064	0.060

TABLE 42 RESISTANCE CHANGE DATA FOR SPECIMEN #30

SPECIMEN NO. = 30

ALT STRAIN = 1000 MEAN STRAIN = 1000 NOM. TEMP = 0.0

INTIAL ZERO READING	1T	2T	3T	4T
	-0.364	-0.228	0.170	0.190

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1T	2T	3T	4T
1.	10.	0.7	0.029	0.024	0.003	0.002
2.	25.	0.5	0.060	0.060	0.003	0.002
3.	50.	-0.3	0.098	0.113	0.002	0.002
4.	100.	-0.3	0.166	0.200	0.0	0.002
5.	150.	0.8	0.230	0.280	0.004	0.010
6.	200.	0.0	0.288	0.353	0.006	0.008
7.	300.	0.1	0.392	0.486	0.008	0.009
8.	500.	0.0	0.576	0.723	0.008	0.012
9.	700.	-0.7	0.736	0.928	0.004	0.010
10.	1000.	0.2	0.948	1.200	0.004	0.008
11.	1500.	0.3	1.266	1.598	0.008	0.016
12.	2000.	0.0	1.526	1.915	0.007	0.018
13.	3000.	0.2	1.950	2.422	0.010	0.020
14.	5000.	-0.3	2.562	3.119	0.012	0.024
15.	7000.	0.0	2.987	3.590	0.010	0.030
16.	9000.	0.0	3.309	3.930	0.013	0.036
17.	10000.	-0.4	3.426	4.051	0.012	0.035
18.	15000.	-0.8	3.934	4.594	0.015	0.041
19.	20000.	-0.4	4.279	4.948	0.017	0.050
20.	25000.	0.3	4.540	5.207	0.016	0.048
21.	30000.	0.3	4.738	5.400	0.017	0.056
22.	40000.	0.9	5.052	5.712	0.020	0.058
23.	50000.	0.7	5.284	5.932	-0.015	0.0
24.	65000.	1.3	5.538	6.176	0.0	0.0
25.	80000.	1.5	5.732	6.365	0.0	0.0
25.	91700.	0.3	5.847	6.478	0.0	0.0
25.	91700.	1.1	5.826	6.465	0.0	0.0
26.	100000.	0.4	5.904	6.538	0.0	0.0
27.	100000.	77.8	5.715	6.328	0.0	0.0

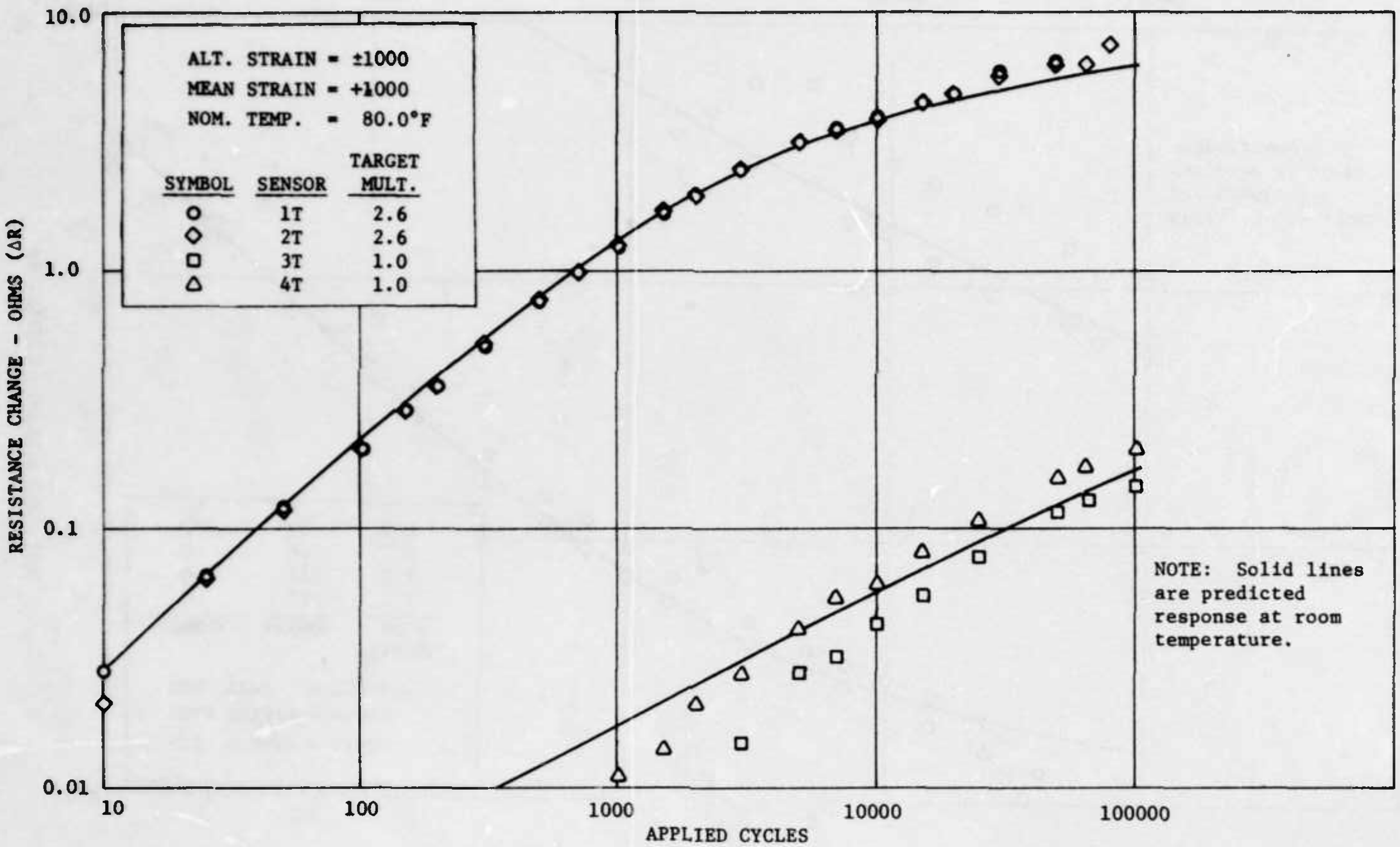

Figure 71 Operational Temperature Response For Specimen #27

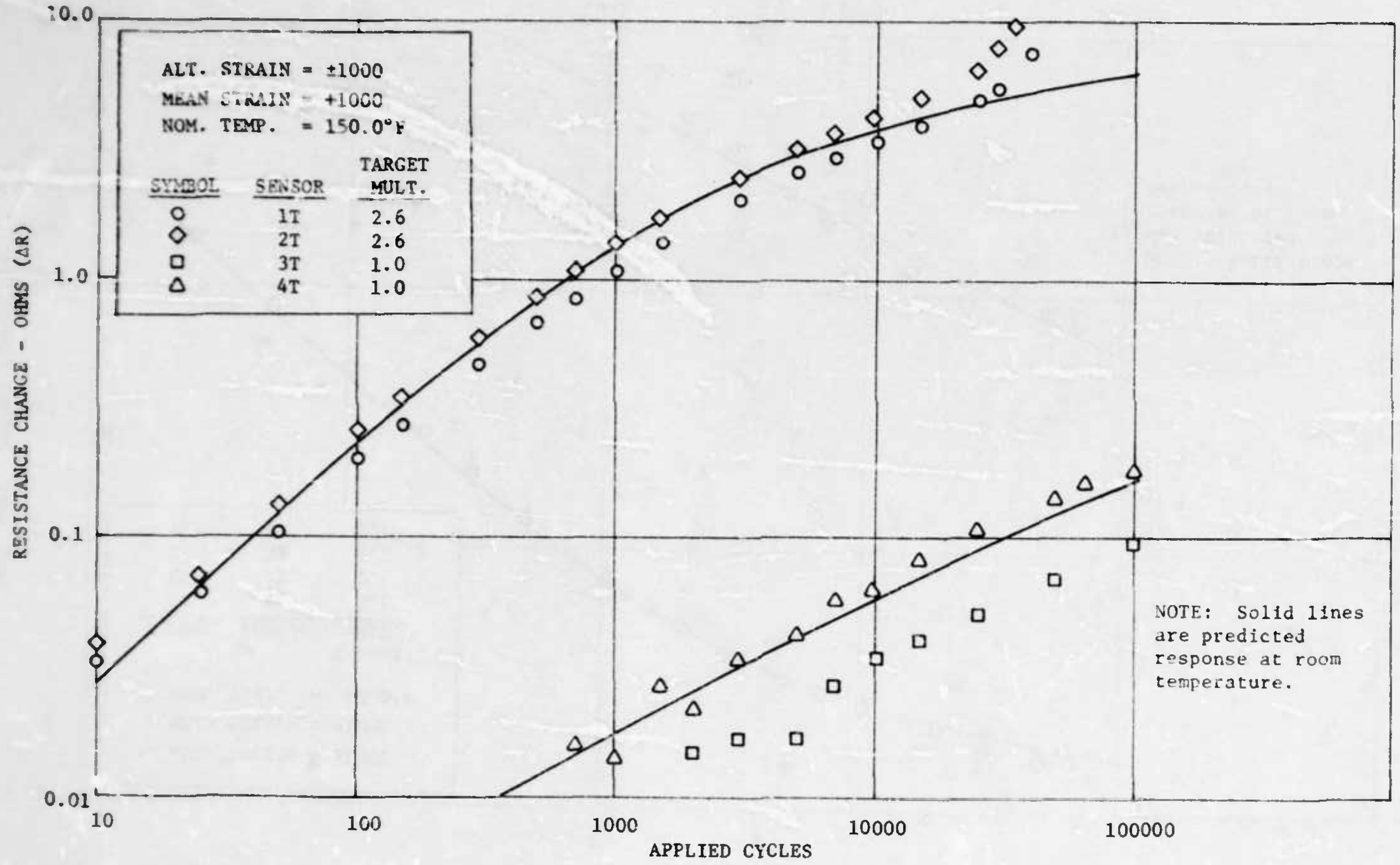

Figure 72 Operational Temperature Response For Specimen #28

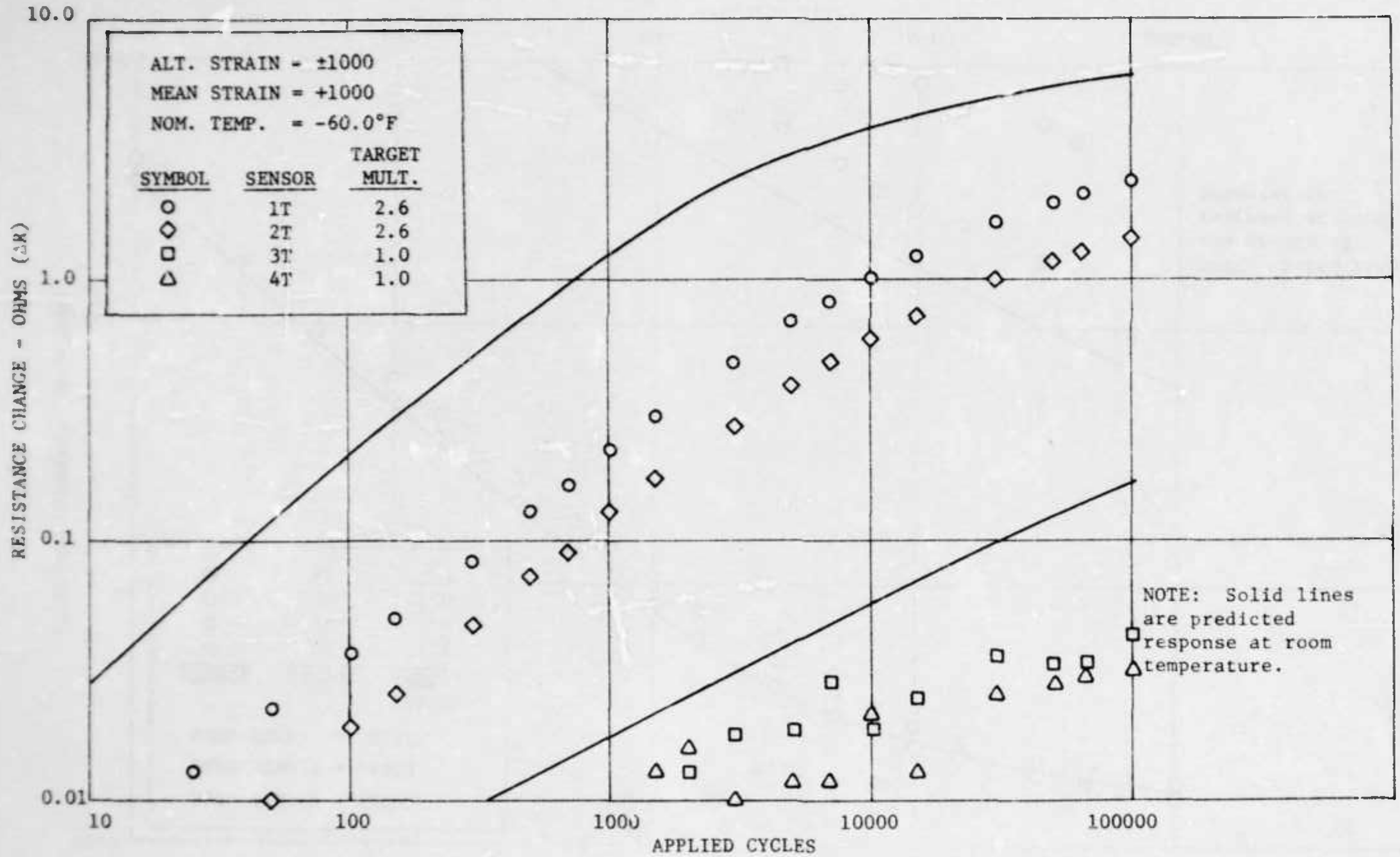

Figure /3 Operational Temperature Response For Specimen #29

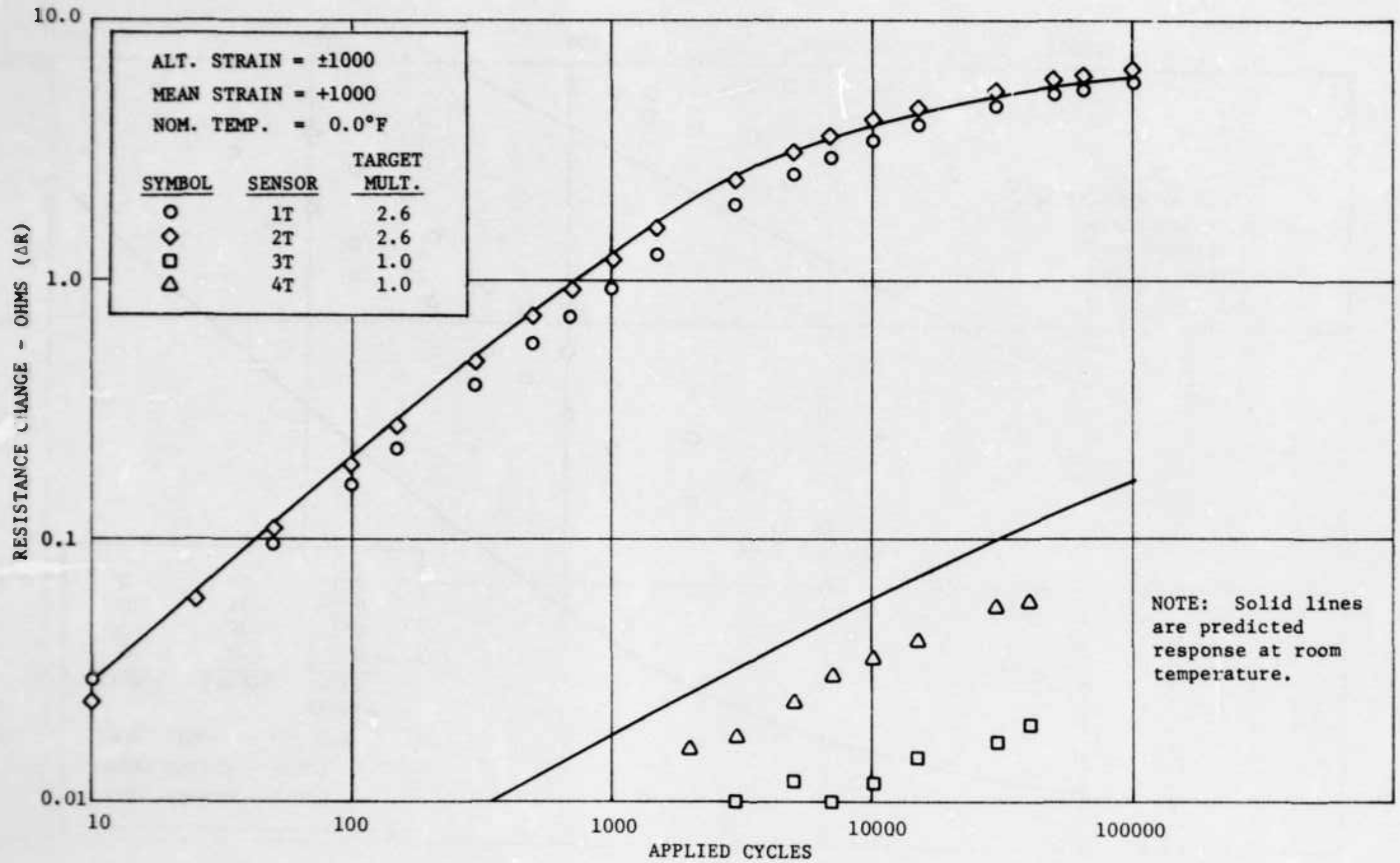

Figure 74 Operational Temperature Response For Specimen #30

TABLE 43 RESISTANCE CHANGE DATA FOR
FOR SPECIMENS #31 AND #32

SPECIMEN NO. = 31 & 32

TEMP CYCLE = +150 TO -50 DEG.F. ZERO TEMP = 55.9

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
⚠	-0.294	-0.114	-0.094	-0.022	-0.504	-0.556

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
3.	2.	51.2	-0.004	-0.004	-0.004	0.002	-0.001	-0.002
4.	3.	50.8	-0.004	-0.006	-0.005	0.0	-0.002	-0.002
5.	4.	48.2	-0.004	-0.007	-0.006	0.008	-0.001	0.001
6.	5.	51.6	-0.006	-0.010	-0.008	0.002	-0.004	-0.002
7.	6.	48.2	-0.005	-0.006	-0.006	0.007	-0.003	-0.001
8.	7.	50.8	-0.008	-0.008	-0.003	0.002	-0.004	-0.002
9.	8.	50.3	-0.004	-0.010	-0.001	0.002	-0.003	-0.002
10.	9.	51.4	-0.005	-0.012	-0.003	0.003	-0.003	-0.001
11.	10.	51.7	-0.002	-0.012	0.0	0.005	-0.003	-0.002
12.	11.	51.5	0.0	-0.010	-0.002	0.003	-0.004	-0.003
13.	15.	50.2	0.0	-0.010	-0.002	0.008	-0.002	0.0
14.	20.	50.5	-0.006	-0.005	0.003	0.003	-0.006	-0.004
15.	25.	51.0	0.004	-0.004	0.0	0.011	0.006	0.012
16.	26.	49.3	0.002	-0.007	-0.004	0.010	-0.002	0.004
17.	30.	49.6	-0.004	-0.012	-0.007	0.006	-0.005	0.0
18.	40.	51.4	0.0	-0.009	-0.006	0.008	-0.004	0.0
19.	45.	51.0	0.002	-0.006	-0.004	0.010	-0.002	0.0
20.	50.	50.1	0.004	-0.004	-0.002	0.012	0.0	0.004
21.	51.	50.8	0.003	-0.002	-0.002	0.010	0.0	0.003

⚠ Zero cycle reading taken at 75.5°F. Reading at 1 cycle used as initial zero for Delta R calculations

TABLE 43 RESISTANCE CHANGE DATA FOR SPECIMENS #31 AND #32 (CONCLUDED)

SPECIMEN NO. = 31 & 32

TEMP CYCLE = +150 TO -50 DEG.F. ZERO TEMP = 55.9

INTIAL ZERO READING	7U	8L	1S	2S △	3S △	4S
△	0.156	0.014	0.072	-0.100	0.284	-0.101

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	7U	8L	1S	2S	3S	4S
3.	2.	51.2	-0.001	-0.001	0.006	0.0	0.0	0.003
4.	3.	50.8	-0.002	-0.002	0.006	0.0	0.0	0.009
5.	4.	48.2	0.004	0.003	0.004	0.0	0.0	0.004
6.	5.	51.6	-0.002	-0.002	0.007	0.0	0.0	0.013
7.	6.	48.2	0.0	0.0	0.016	0.0	0.0	0.005
8.	7.	50.8	-0.002	-0.002	0.013	0.0	0.0	0.004
9.	8.	50.3	-0.001	-0.001	0.010	0.0	0.0	0.002
10.	9.	51.4	-0.001	0.0	0.014	0.0	0.0	-0.001
11.	10.	51.7	-0.001	0.0	0.008	0.0	0.0	0.004
12.	11.	51.5	-0.004	0.0	-0.008	0.0	0.0	0.004
13.	15.	50.2	0.0	0.005	-0.002	0.006	0.001	0.009
14.	20.	50.5	0.0	0.003	0.0	-0.002	0.003	0.006
15.	25.	51.0	0.004	0.007	-0.005	-0.002	0.003	0.009
16.	26.	49.3	0.0	0.005	-0.005	-0.003	0.001	0.009
17.	30.	49.6	0.0	0.007	-0.005	0.0	0.006	0.013
18.	40.	51.4	0.003	0.008	-0.003	-0.002	0.007	0.011
19.	45.	51.0	0.0	0.005	-0.005	-0.006	-0.002	-0.003
20.	50.	50.1	0.004	0.008	0.001	-0.001	0.006	0.010
21.	51.	50.8	0.003	0.005	0.006	0.004	0.012	0.012

△ See note 1

△ Instrumentation problem identified as poor switch contact. Switching system cleaned and repaired at 10 cycles. Cycle 11 used as zero reading for these sensors.

TABLE 44 CYCLIC TEMPERATURE TEST FOR SPECIMENS #31 AND #32
(APPARENT STRAIN CYCLE #1)

CYCLIC TEMPERATURE TEST — SPECIMEN NO. = 31&32

APPARENT STRAIN CYCLES — TEMP = +150 TO-50 DEG.F.

APPARENT STRAIN CYCLE NO.= 1 — NO. OF APPLIED TEMP CYCLES = 0.

SEN NO.	APPARENT STRAIN (S.G.) 150 DEG	50 DEG	-50 DEG	APPARENT STRAIN (F.S.) 150 DEG	50 DEG	-50 DEG
1U	1870.	31.	-1981.	1726.	67.	-2112.
2M	1845.	38.	-1942.	1739.	54.	-2144.
3L	1848.	25.	-1959.	1751.	49.	-2125.
4U	1515.	-12.	-2007.	1238.	-2.	-1908.
5M	1762.	18.	-1974.	1780.	40.	-2131.
6L	1796.	34.	-2052.	1833.	37.	-2246.
7U	603.	14.	-782.	569.	50.	-958.
8L	610.	14.	-795.	576.	54.	-959.
1S	346.	38.	-450.	288.	132.	-580.
2S	323.	5.	-408.	259.	63.	-589.
3S	327.	28.	-445.	245.	-12.	-558.
4S	380.	12.	-434.	366.	20.	-617.

Note: Apparent strains are calculated using final 50°F reading as zero strain

SEN NO.	APPARENT ALTERNATING STRAIN (S.G.)	APPARENT ALTERNATING STRAIN (F.S.)
1U	1925.500	1919.000
2M	1893.500	1941.500
3L	1903.500	1938.000
4U	1761.000	1573.000
5M	1868.000	1955.500
6L	1924.000	2039.500
7U	692.500	763.500
8L	702.500	767.500
1S	398.000	434.000
2S	365.500	424.000
3S	386.000	401.500
4S	407.000	491.500

TABLE 45 CYCLIC TEMPERATURE TEST FOR SPECIMENS #31 AND #32
(APPARENT STRAIN CYCLE #2)

CYCLIC TEMPERATURE TEST SPECIMEN NO. = 31&32

APPARENT STRAIN CYCLES TEMP = +150 TO-50 DEG.F.

APPARENT STRAIN CYCLE NO.= 2 NO. OF APPLIED TEMP CYCLES = 5.

SEN NO.	APPARENT STRAIN (S.G.) 150 DEG	50 DEG	-50 DEG	APPARENT STRAIN (F.S.) 150 DEG	50 DEG	-50 DEG
1U	1973.	145.	-1934.	1888.	176.	-2059.
2M	1944.	135.	-1900.	1917.	165.	-2089.
3L	1960.	129.	-1928.	1915.	168.	-2081.
4U	1653.	148.	-1994.	1405.	163.	-1880.
5M	1685.	-65.	-2129.	1903.	145.	-2063.
6L	1923.	157.	-2018.	1958.	140.	-2172.
7U	662.	50.	-784.	643.	52.	-907.
8L	671.	52.	-792.	637.	46.	-909.
1S	385.	-8.	-496.	299.	-40.	-630.
2S	363.	-31.	-426.	242.	-82.	-670.
3S	378.	16.	-475.	197.	-184.	-691.
4S	367.	-42.	-445.	341.	-8.	-652.

Note: Apparent strains are calculated using final 50°F reading as zero strain

SEN NO.	APPARENT ALTERNATING STRAIN (S.G.)	APPARENT ALTERNATING STRAIN (F.S.)
1U	1953.500	1973.500
2M	1922.000	2003.000
3L	1944.000	1998.000
4U	1823.500	1642.500
5M	1907.000	1983.000
6L	1970.500	2065.000
7U	723.000	775.000
8L	731.500	773.000
1S	440.500	464.500
2S	394.500	456.000
3S	426.500	444.000
4S	406.000	496.500

TABLE 46 CYCLIC TEMPERATURE TEST FOR SPECIMENS #31 AND #32
(APPARENT STRAIN CYCLE #3)

CYCLIC TEMPERATURE TEST SPECIMEN NO. = 31&32

APPARENT STRAIN CYCLES TEMP = +150 TO-50 DEG.F.

APPARENT STRAIN CYCLE NO.= 3 ⚠ NO. OF APPLIED TEMP CYCLES =10.

SEN NO.	APPARENT STRAIN (S.G.) 150 DEG	50 DEG	-50 DEG	APPARENT STRAIN (F.S.) 150 DEG	50 DEG	-50 DEG
1U	2003.	2.	-2048.	1902.	-27.	-2182.
2M	1966.	12.	-2005.	1936.	-20.	-2196.
3L	1992.	10.	-2035.	1939.	-24.	-2199.
4U	1652.	-36.	-2102.	1418.	-64.	-2004.
5M	1929.	-3.	-2057.	1951.	-17.	-2195.
6L	1943.	11.	-2144.	1980.	-2.	-2298.
7U	678.	-20.	-836.	666.	-36.	-1012.
8L	694.	-21.	-841.	665.	-29.	-1005.
1S	553.	26.	-474.	625.	18.	-618.
2S	492.	18.	-428.	936.	9.	-662.
3S	667.	8.	-504.	758.	3.	-685.
4S	754.	15.	-497.	674.	2.	-694.

Note: Apparent strains are calculated using final 50°F reading as zero strain

SEN NO.	APPARENT ALTERNATING STRAIN (S.G.)	APPARENT ALTERNATING STRAIN (F.S.)
1U	2025.500	2042.000
2M	1985.500	2066.000
3L	2013.500	2069.000
4U	1877.000	1711.000
5M	1993.000	2073.000
6L	2043.500	2139.000
7U	757.000	839.000
8L	767.500	835.000
1S	513.500	621.500
2S	460.000	799.000
3S	585.500	721.500
4S	625.500	684.000

⚠ Apparent strain cycle No. 3 shown for continuity only. Eratic data due to instrumentation problem discussed under sensor response data.

TABLE 47 CYCLIC TEMPERATURE TEST FOR SPECIMENS #31 AND #32
(APPARENT STRAIN CYCLE #4)

CYCLIC TEMPERATURE TEST SPECIMEN NO. = 31&32

APPARENT STRAIN CYCLES TEMP = +150 TO-50 DEG.F.

APPARENT STRAIN CYCLE NO.= 4 NO. OF APPLIED TEMP CYCLES =25.

SEN NO.	APPARENT STRAIN (S.G.) 150 DEG	50 DEG	-50 DEG	APPARENT STRAIN (F.S.) 150 DEG	50 DEG	-50 DEG
1U	1819.	-3.	-2019.	1730.	-6.	-2203.
2M	1800.	9.	-1985.	1769.	3.	-2230.
3L	1835.	11.	-2014.	1772.	1.	-2231.
4U	1529.	36.	-2077.	1289.	36.	-2015.
5M	1745.	14.	-2011.	1762.	35.	-2198.
6L	1768.	66.	-2106.	1802.	104.	-2315.
7U	629.	-40.	-826.	586.	-56.	-1009.
8L	660.	-60.	-815.	594.	-48.	-1008.
1S	348.	111.	-471.	285.	89.	-624.
2S	302.	110.	-445.	260.	96.	-658.
3S	317.	82.	-496.	259.	123.	-678.
4S	332.	119.	-474.	284.	103.	-692.

Note: Apparent strains are calculated using final 50°F reading as zero strain

SEN NO.	APPARENT ALTERNATING STRAIN (S.G.)	APPARENT ALTERNATING STRAIN (F.S.)
1U	1919.000	1966.500
2M	1892.500	1999.500
3L	1924.500	2001.500
4U	1803.000	1652.000
5M	1878.000	1980.000
6L	1937.000	2058.500
7U	727.500	797.500
8L	737.500	801.000
1S	409.500	454.500
2S	373.500	459.000
3S	406.500	468.500
4S	403.000	488.000

TABLE 48 CYCLIC TEMPERATURE TEST FOR SPECIMENS #31 AND #32
(APPARENT STRAIN CYCLE #5)

CYCLIC TEMPERATURE TEST SPECIMEN NO. = 31&32

APPARENT STRAIN CYCLES TEMP = +150 TO-50 DEG.F.

APPARENT STRAIN CYCLE NO.= 5 NO. OF APPLIED TEMP CYCLES =50.

SEN NO.	APPARENT STRAIN (S.G.) 150 DEG	50 DEG	-50 DEG	APPARENT STRAIN (F.S.) 150 DEG	50 DEG	-50 DEG
1U	1783.	-52.	-2030.	1715.	-55.	-2202.
2M	1759.	-62.	-1998.	1739.	-74.	-2246.
3L	1789.	-60.	-2024.	1765.	-48.	-2225.
4U	1502.	-57.	-2111.	1305.	-35.	-2015.
5M	1716.	-41.	-2024.	1744.	-36.	-2187.
6L	1727.	-32.	-2132.	1771.	-27.	-2309.
7U	664.	-8.	-824.	658.	0.	-984.
8L	681.	-13.	-825.	658.	-1.	-994.
1S	411.	37.	-494.	312.	18.	-652.
2S	390.	45.	-454.	311.	5.	-673.
3S	382.	38.	-489.	321.	25.	-697.
4S	412.	57.	-482.	327.	2.	-713.

Note: Apparent strains are calculated using final 50°F reading as zero strain.

SEN NO.	APPARENT ALTERNATING STRAIN (S.G.)	APPARENT ALTERNATING STRAIN (F.S.)
1U	1906.500	1958.500
2M	1878.500	1992.500
3L	1906.500	1995.000
4U	1806.500	1660.000
5M	1870.000	1965.500
6L	1929.500	2040.000
7U	744.000	821.000
8L	753.000	826.000
1S	452.500	482.000
2S	422.000	492.000
3S	435.500	509.000
4S	447.000	520.000

SECTION VII

FM MULTIPLIER PERFORMANCFS

7.1 INTRODUCTION

The Micro-Measurements FM Fatigue Sensor was the primary instrument evaluated by this laboratory test series. The FM Multiplier Performance is integral to the performance of the FM Fatigue Sensor; six parameters of FM Multiplier Performance were evaluated using test data.

a) Effective Strain Multiplication

b) Multiplier Endurance/Stability

c) Strain Compensation

d) Operational Strain Limits

e) Temperature Limits

f) Creep

These parameters are discussed on an individual basis in the following paragraphs.

7.2 EFFECTIVE MULTIPLIER

The FM type mechanical multiplier is shown by Figure 79 . This device operates by taking specimen elongation along a specified "Gage Length" and transmitting this strain via stainless steel extenders to the fatigue sensor element. The distance between the mounting feet (gage length) is the major parameter in establishing the effective multiplication of the assembly.

The FM fatigue sensor manufacturer (Micro-Measurements) has established the required multiplier dimensions and supplies each sensor with a preset multiplier value subject to a tolerance of (±5%).

During the constant amplitude test series (section 2.1), static load cycles were performed at periodic intervals of sensor life to check multiplier performance. Table F-4 documents the calculation of effective multiplication for a typical constant amplitude test (specimen #6). Table 49 summarizes the calculated effective multiplier for each of four multipliers tested. These data show the FM multiplier generally met manufacturer's specified tolerances (±5%) in terms of:

a) Preset Target Value

b) Repeatability of Multiple Installations

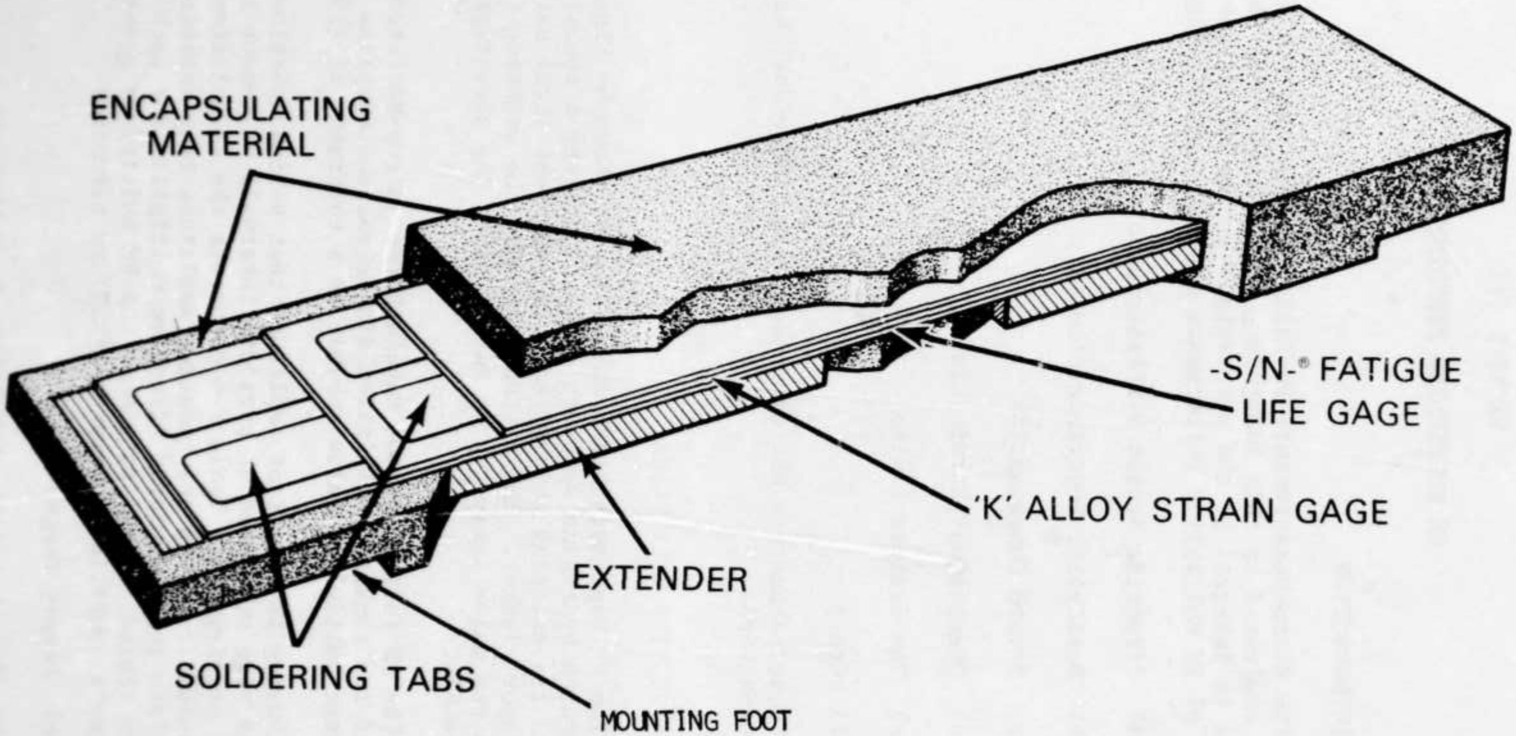

Figure 79 FM - Series Multiplier

TABLE 49 AVERAGE EFFECTIVE MULTIPLIERS

SENSOR	1U	2M	3L	4U	5M	6L
1) Manufacturers Target Value	2.5	2.5	2.5	2.0	3.0	3.5
2) Manufacturers Specified Tolerance	±.1	±.1	±.1	±.1	±.2	±.2
3) Average Test Multiplier - all sensors on all specimens	2.63	2.62	2.62	2.05	3.04	3.42
4) Total Number of Samples in Item (3)	389	427	405	438	352	333
5) Average of Maximum Deviations from the Multiplier Mean Value for Each Sensor Tested*						
Average Positive Deviation	+.10	+.09	+.10	+.08	+.09	+.12
Average Negative Deviation	-.09	-.09	-.10	-.10	-.09	-.11
Percentage Deviation	+3.8% -3.4%	+3.4% -3.4%	+3.8% -3.8%	+3.9% -4.9%	+3.0% -3.0%	+3.5% -3.2%
6) Average of Maximum Absolute Deviations from Values of Item (3) for each Sensor						
Average Positive Deviation	+.11	+.11	+.11	+.09	+.11	+.14
Average Negative Deviation	-.10	-.10	-.10	-.09	-.12	-.13
Percentage Deviation	+4.2% -3.8%	+4.2% -3.8%	+4.2% -3.8%	+4.4% +4.4%	+3.6% -3.9%	+4.1% -3.8%

* Multiplier performance for each FM sensor was averaged for a maximum of nine static load cycles with three load levels each (27 data points). The average of the maximum deviation of each sensor from its calculated average multiplier is shown by Item (5).

c) Varying Applied Strain Levels (-2000 to +2500 $\mu\varepsilon$)

The 2.5 multiplier was an exception to manufacturer's specifications with the effective multiplier operating at 2.62. However, a plot (Figure 80) of the multiplier performance versus mounting "foot" dimensions suggests the multiplier potentially will meet specified tolerances. Table 49, Item (6), shows the FM multiplier capability to meet the ±5% tolerance against an absolute multiplier setting.

7.3 MULTIPLIER ENDURANCE AND STABILITY

The effective multiplier performance was checked periodically during sensor life (up to 1,000,000 cycles). Table 49, Item (5), includes data from initial sensor installation to the end of useful sensor life (failure of fatigue sensor element) and demonstrates the multiplier was stable within ±5%. Figures 82 thru 87 are sample plots of effective multiplier performance versus applied cycles as an illustration of multiplier stability and endurance.

The effective multiplier performance did not show signs of deterioration and generally exhibited stability for the duration of each test.

7.4 STRAIN COMPENSATION

One of the major improvements of the FM fatigue sensor over previous models is the strain compensation feature provided by the integral strain gage. The test performance of this strain compensation was checked by the static load cycles performed for each constant amplitude test. Table F-4 shows "Multiplier Stability Calculation" for a typical constant amplitude test (specimen #6). The ohms variation of the composite sensor reading under load, from that at zero load, is shown for all load response cycles. In addition, a "Load Effect Ratio" is calculated for each value of ohms variation from zero. The load effect ratio is defined as the ΔR under load divided by ΔR at zero load. Therefore, a load effect ratio of 1.0 indicates perfect load compensation. Plots of load effect ratio at various values of ΔR are shown in Figures 88 thru 92. All test data at each resistance change (ΔR) level are plotted.

The scatter band limits shown are arbitrary values based on a "95% Confidence Level". Figure 81 is a graphical representation of scatter which may be expected from reading FM fatigue sensor under load variations from -2000 to +2500 $\mu\varepsilon$. Figure 81 indicates the FM fatigue sensor will produce resistance change readings stable within ±5% when resistance change is greater than 0.5 ohms. A comparison of Figure 92 with Figure 90 indicates the strain compensation was virtually identical for all multipliers settings tested (2.0 to 3.5).

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FATIGUE SENSOR EVALUATION PROGRAM LABORATORY TEST REPORT.(U)
OCT 75 R W WALKER, J Y KAUFMAN F33657-71-C-0163
UNCLASSIFIED 318E-7319-047 ASD-TR-75-33 NL

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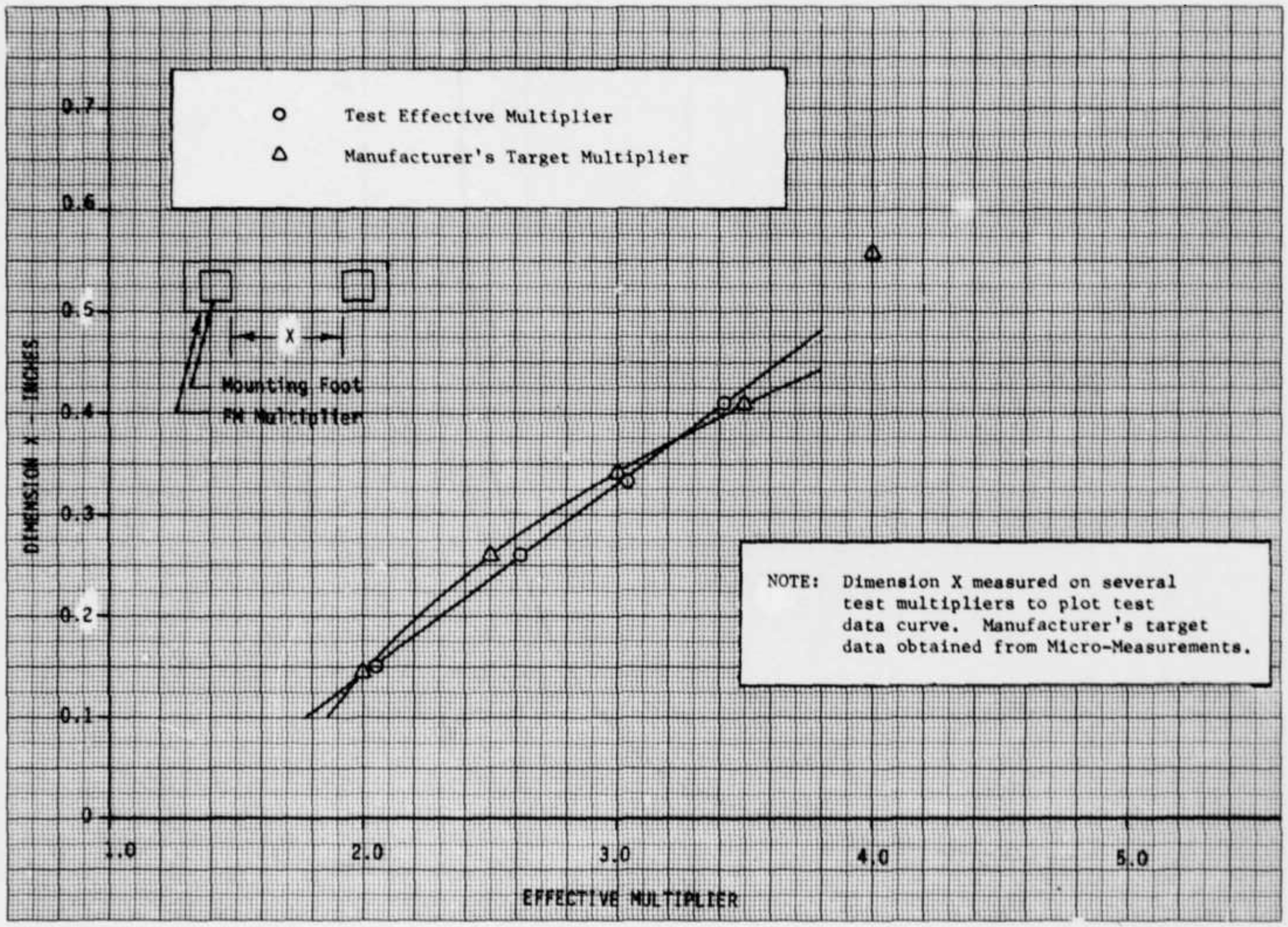

Figure 80 Effective Multiplier Versus Multiplier Spacing Dimension

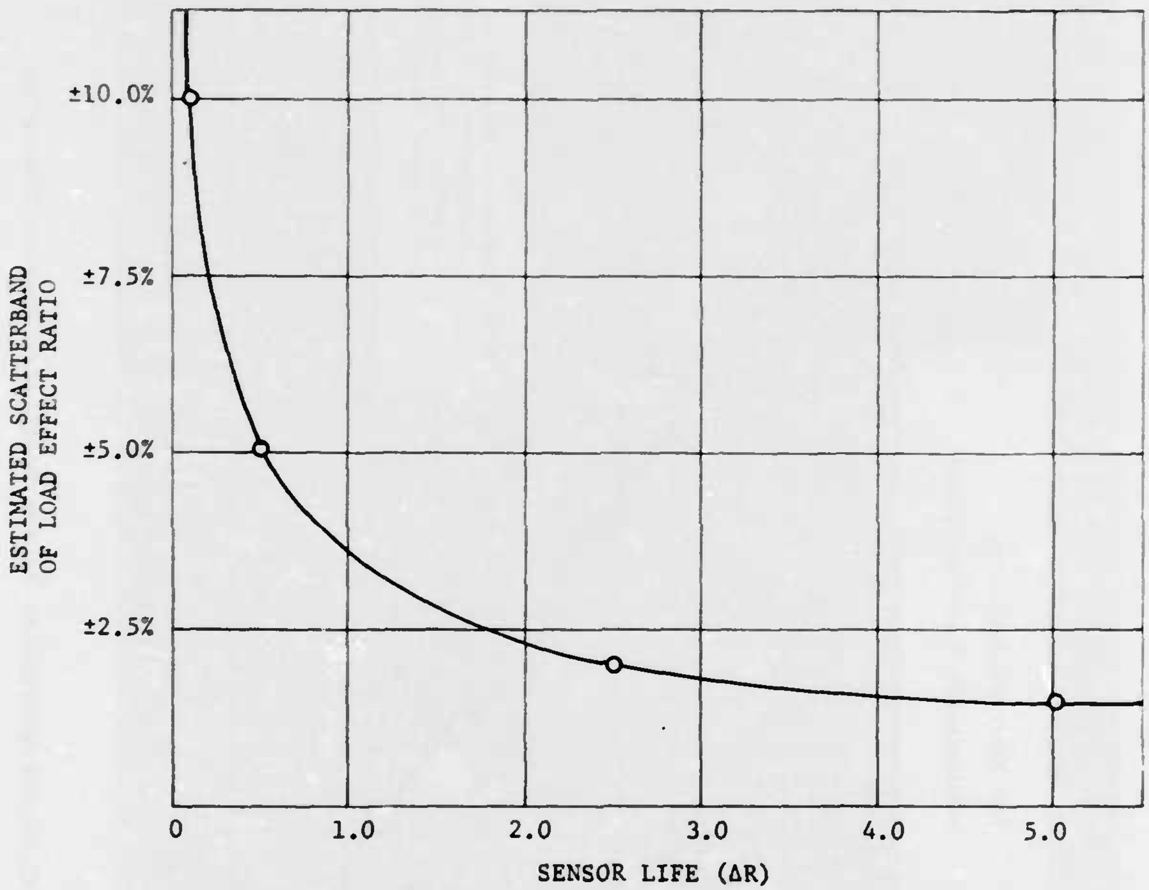

Figure 81 Effective Strain Compensation

7.5 OPERATIONAL STRAIN LIMITS

The operational limits for amplified strain on the FM fatigue sensor/multiplier are estimated to be +7000 and -5000 microstrain. These limits are based on deterioration or failures experienced during the constant amplitude test series when operating at or beyond these limits. For example:

a) For operation above +7000 $\mu\varepsilon$, Sensor 6L on specimens #8 thru #10 consistently failed prematurely.

b) For operation below -5000 $\mu\varepsilon$, Sensor 6L on specimens #11 thru #13 exhibited low multiplier performance and some multiplier instability was noted.

7.6 TEMPERATURE LIMITS

FM fatigue sensor operational temperature limits were established to be -20°F to +130°F (see Figure 59) by the cyclic temperature test data (see section 6.2). The FM multiplier performance deteriorates for operation outside these limits.

7.7 CREEP

High temperature creep (+150°F) or slippage of the FM multiplier assembly was identified during the cyclic temperature tests (see section 6.2).

Room temperature creep of the multiplier was also suspected due to a slight shift in fatigue sensor elements immediately after stopping cycling on the constant amplitude tests (after periods of extended cycling). A room temperature creep test was conducted to determine the existance and magnitude of creep at room temperatures; this test is described in section 2.6.

The results of the room temperature creep test showed a small but measurable effect. These data are plotted by Figures 93 thru 95 The composite fatigue sensor reading was stable within ±0.015 ohms.

It is concluded the FM multiplier creep properties up to +130°F do not significantly alter performance of the FM sensor while the properties above +130°F represent a limitation to the FM sensor.

FM MULTIPLIER PERFORMANCE

SUPPORTING DATA

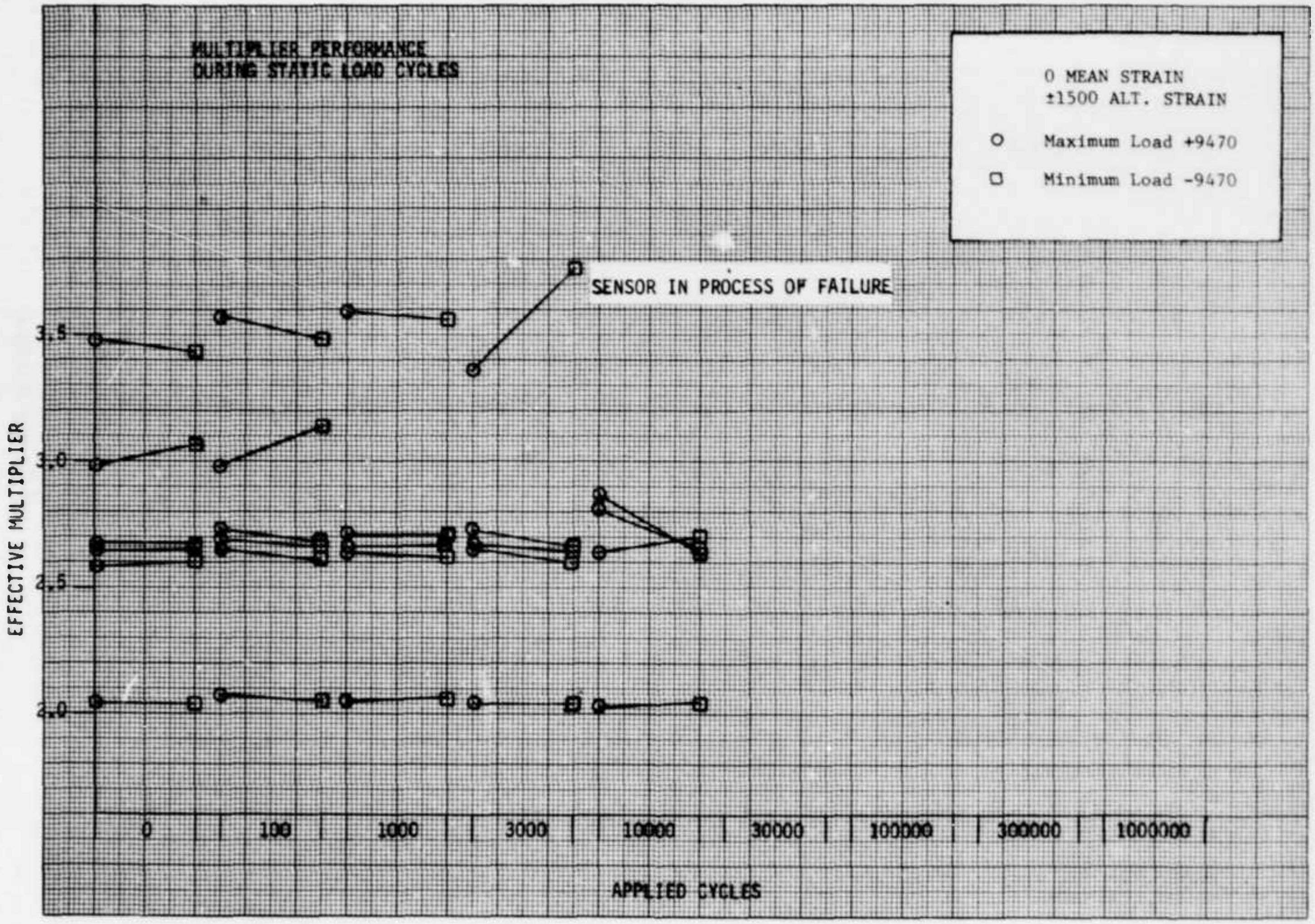

Figure 82 Multiplier Performance, Specimen #5

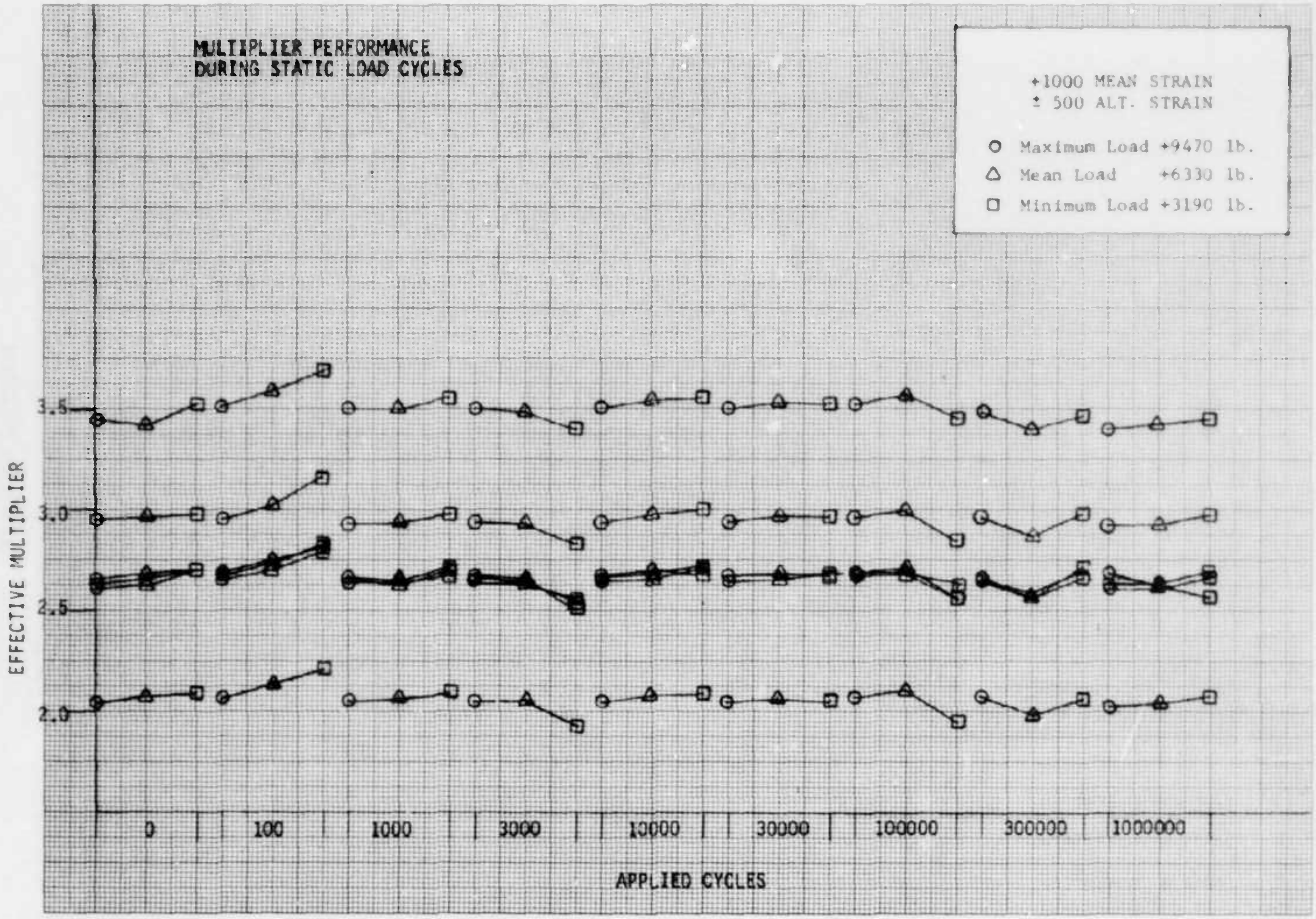

Figure 83 Multiplier Performance, Specimen #6

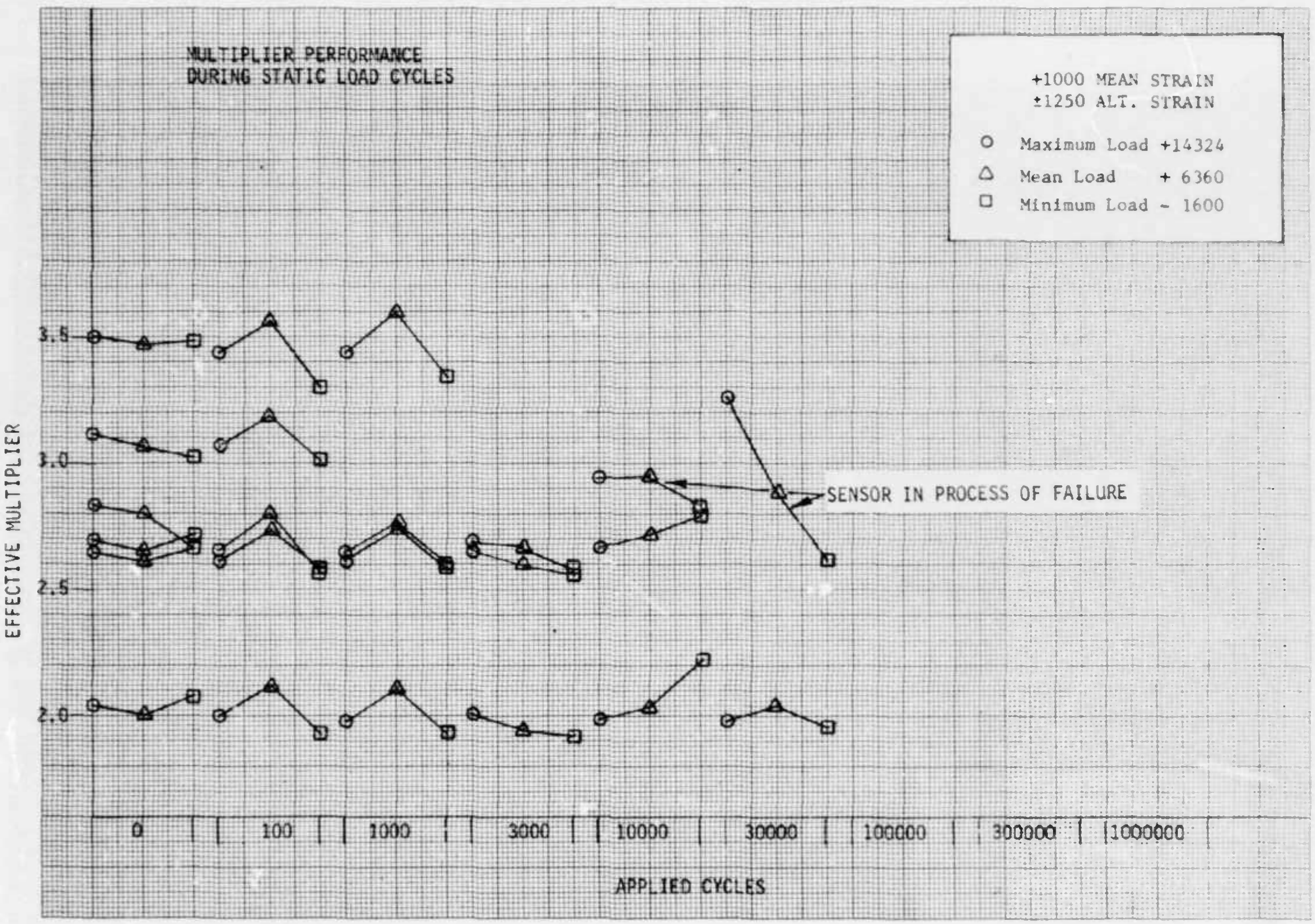

Figure 84 Multiplier Performance, Specimen #9

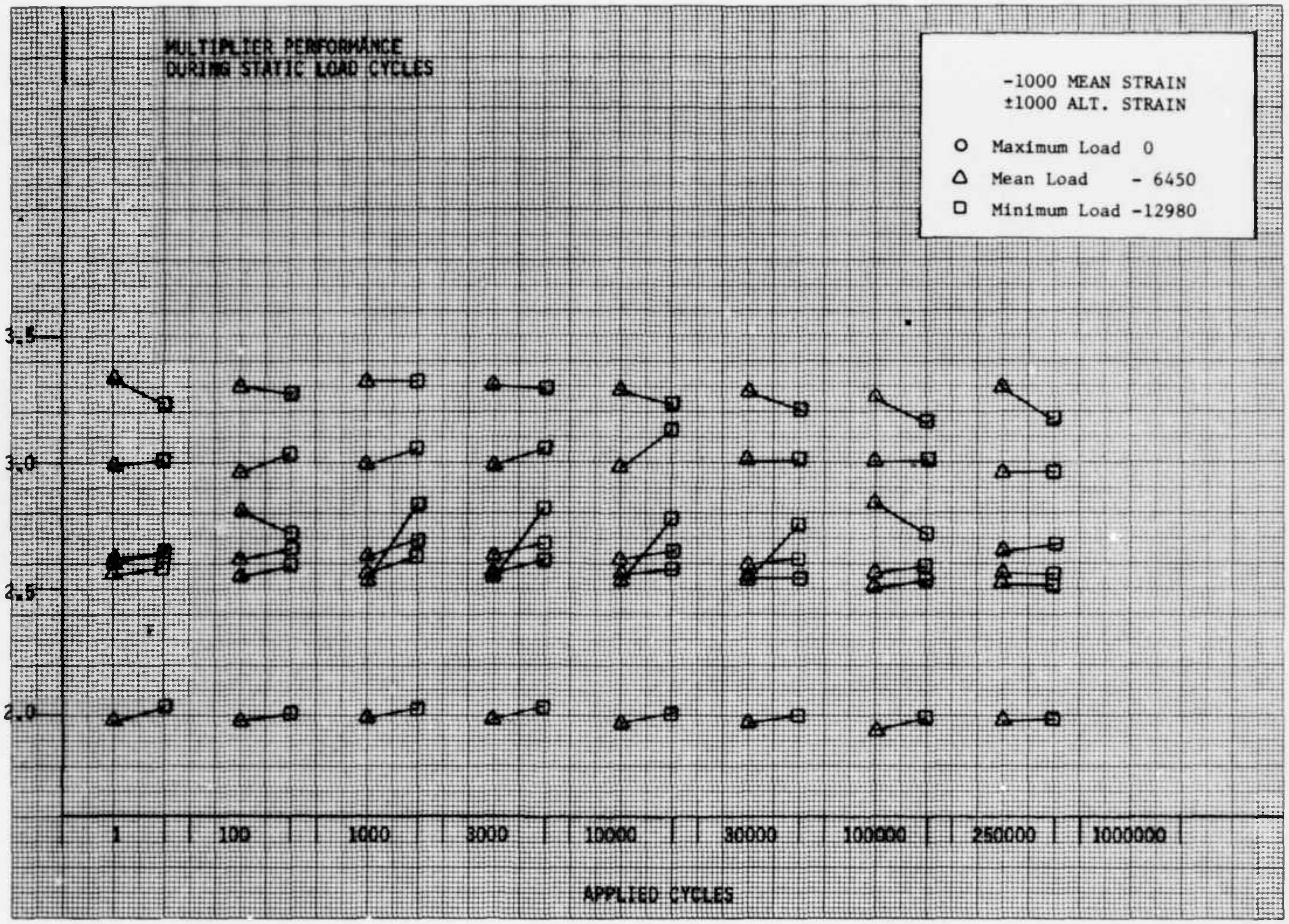

Figure 85 Multiplier Performance, Specimen #13

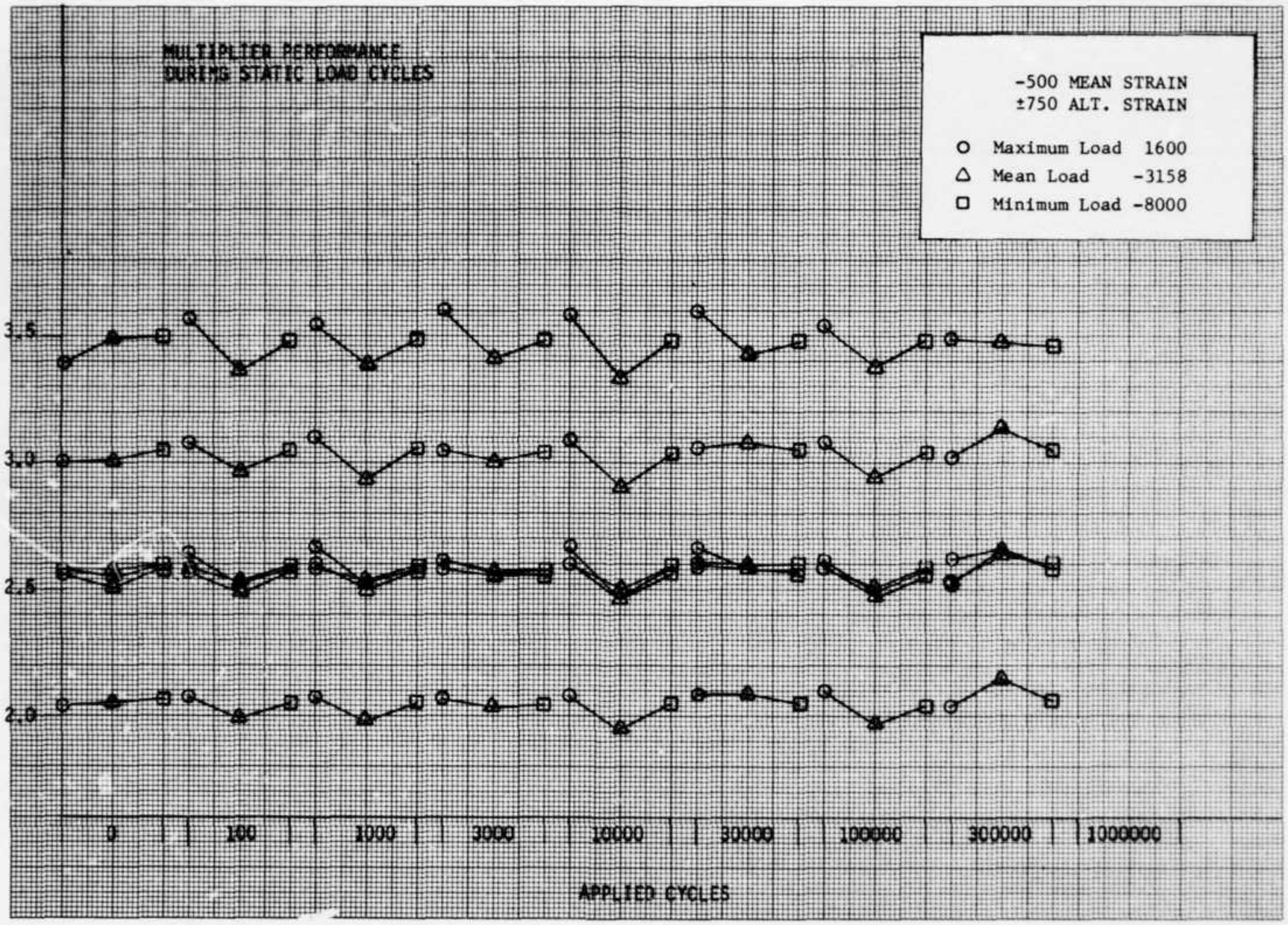

Figure 86 Multiplier Performance, Specimen #15

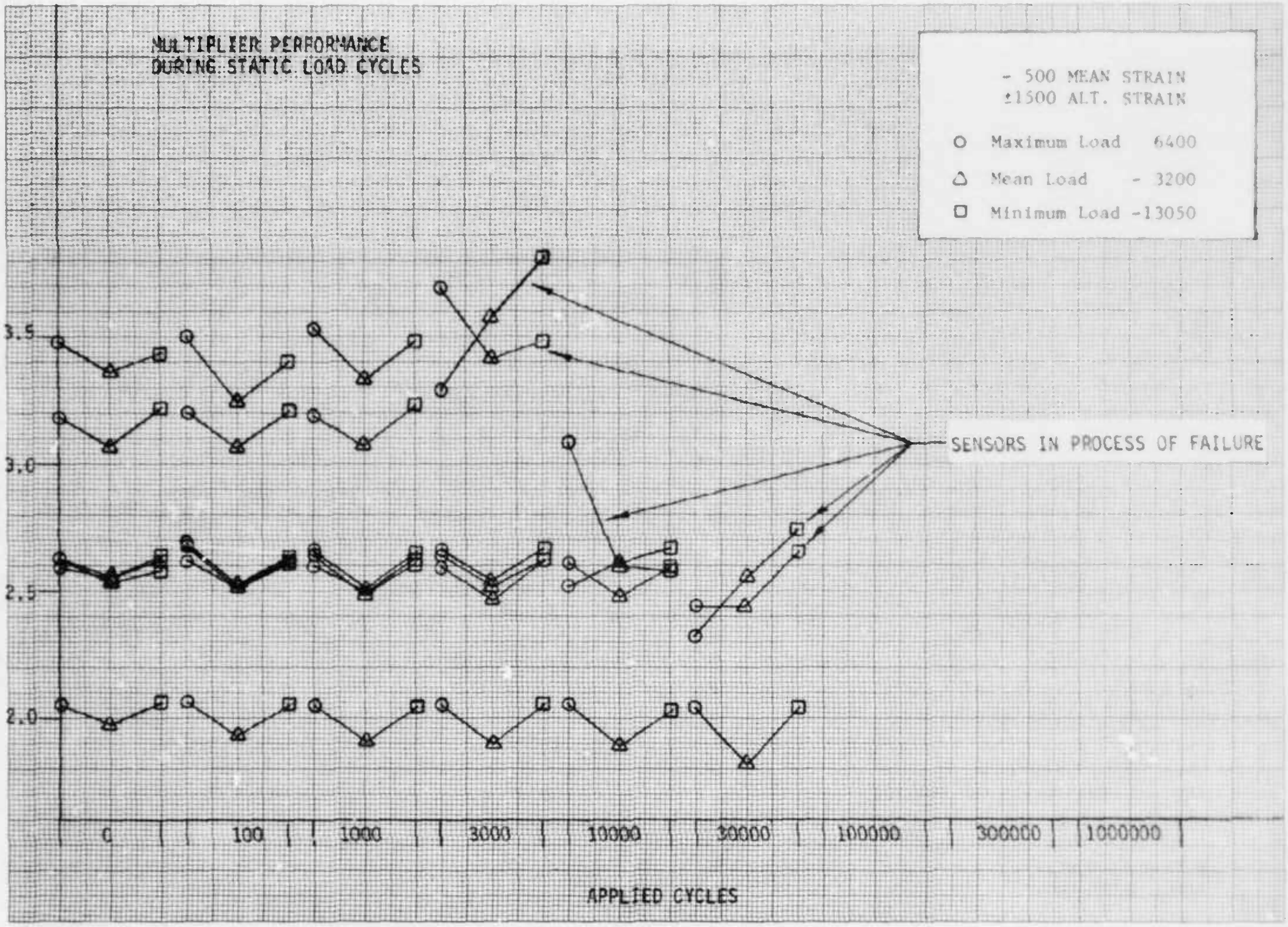

Figure 87 Multiplier Performance, Specimen #18

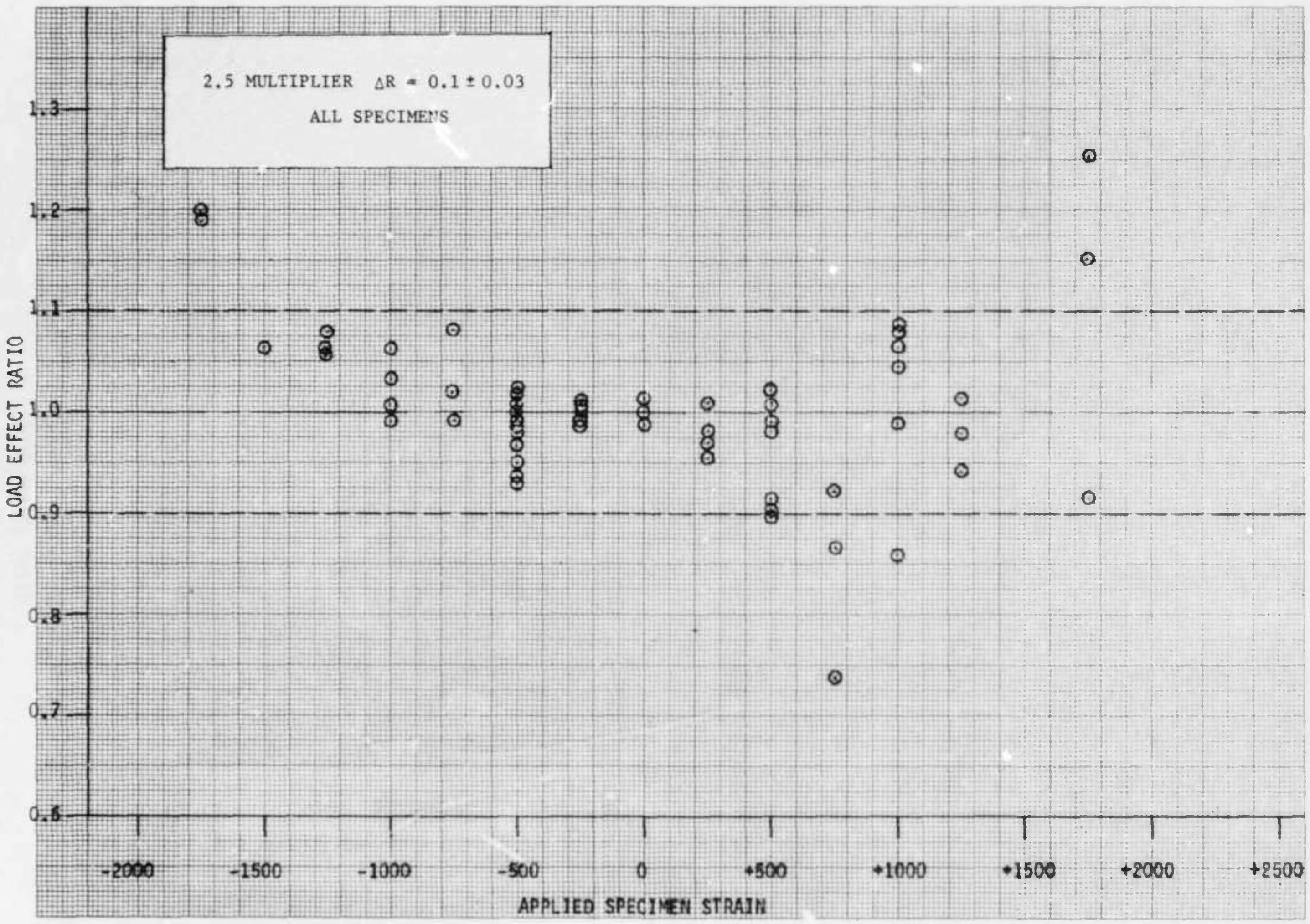

Figure 88 Load Effect Ratio (ΔR=0.1,2.5 Multiplier)

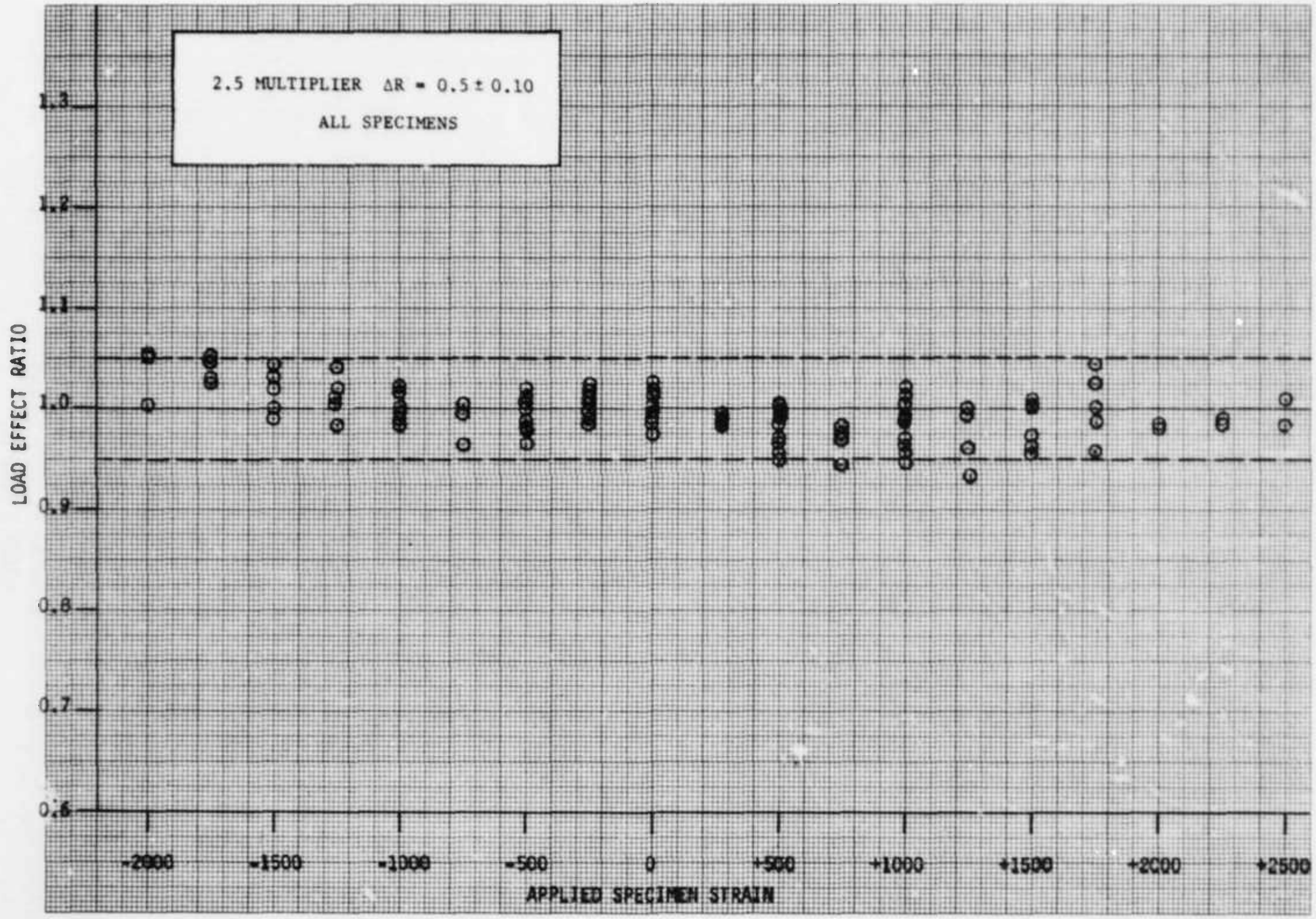

Figure 89 Load Effect Ratio (ΔR=0.5,2.5 Multiplier)

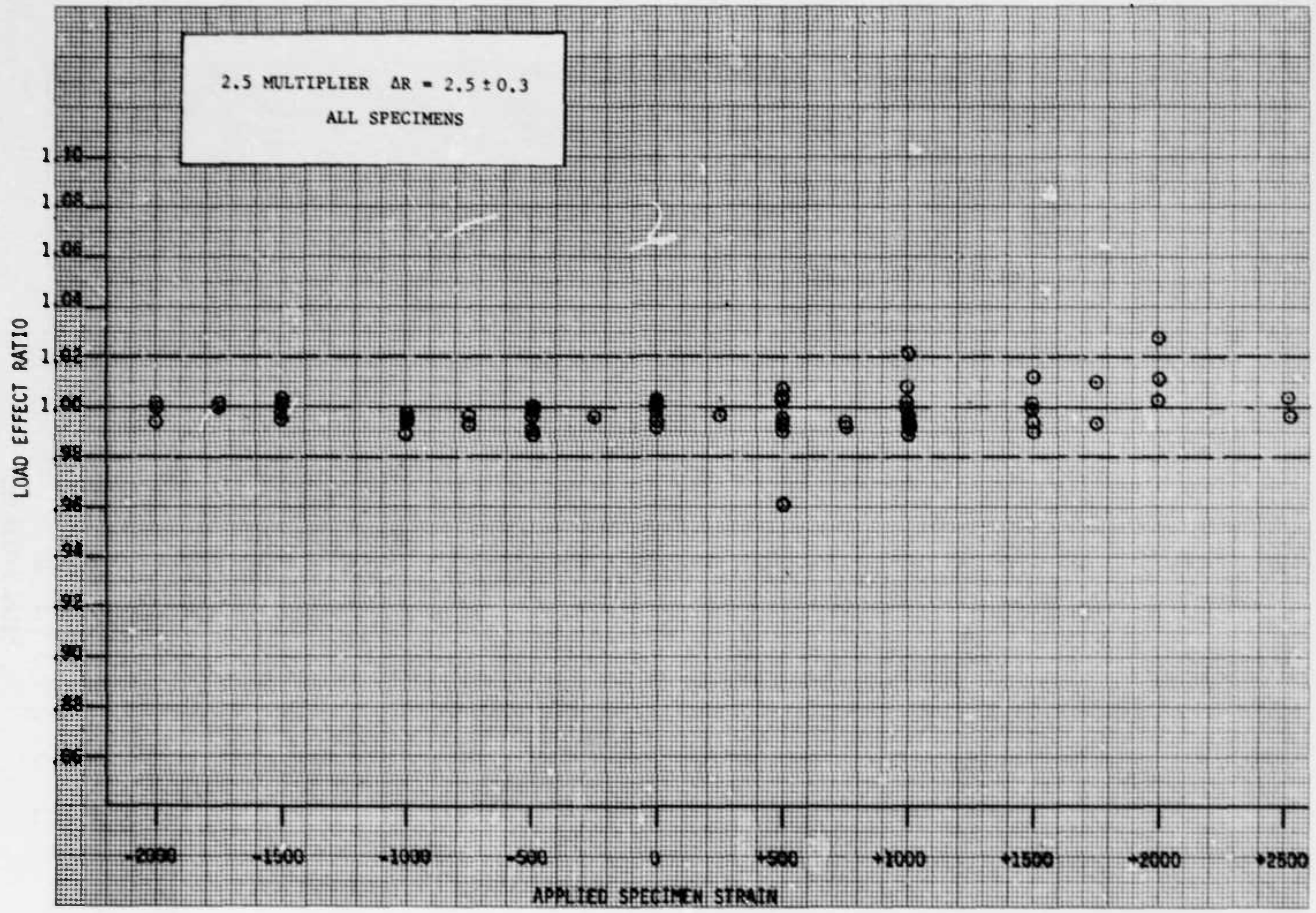

Figure 90 Load Effect Ratio (ΔR=2.5,2.5 Multiplier)

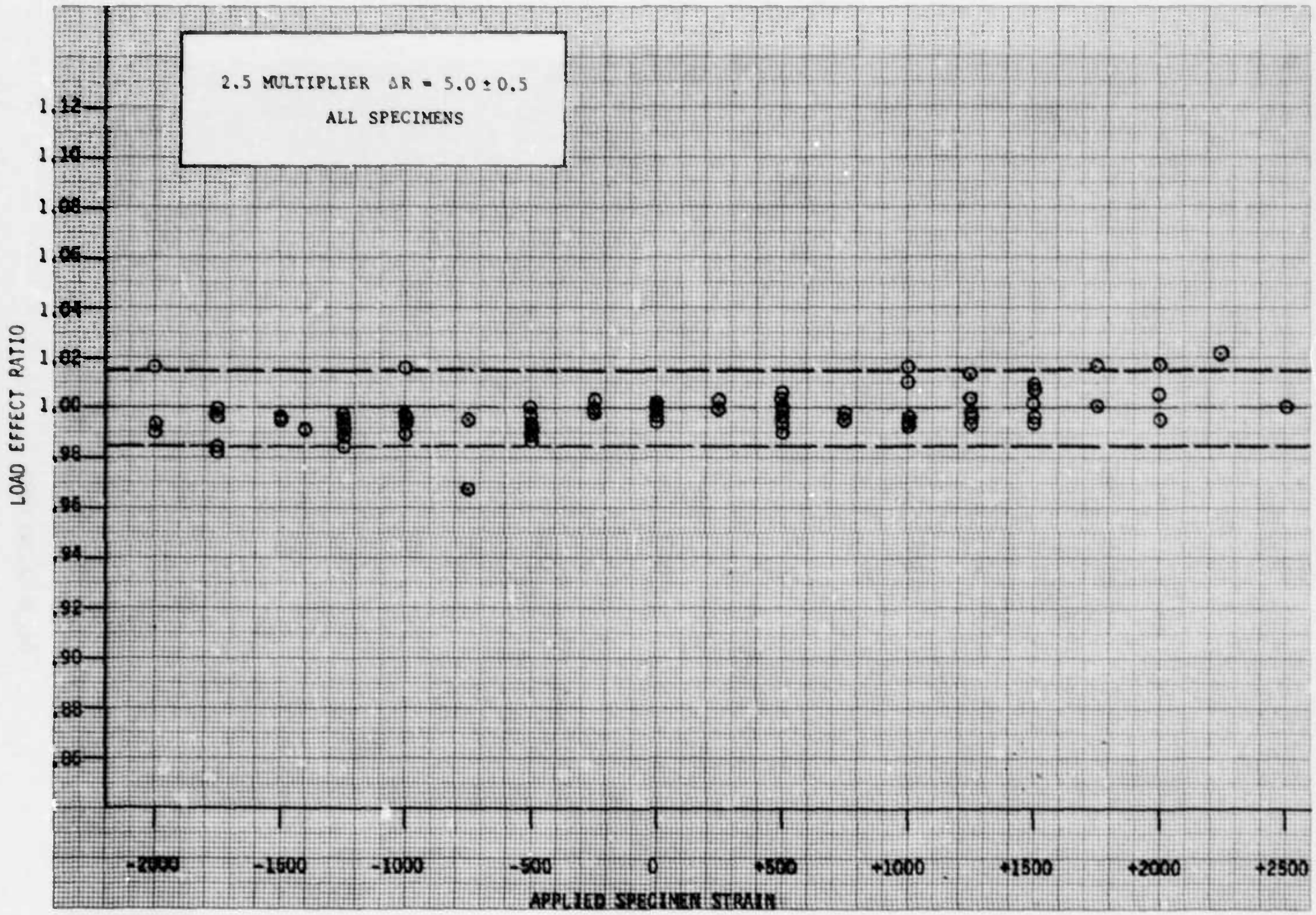

Figure 91 Load Effect Ratio (ΔR=5.0,2.5 Multiplier)

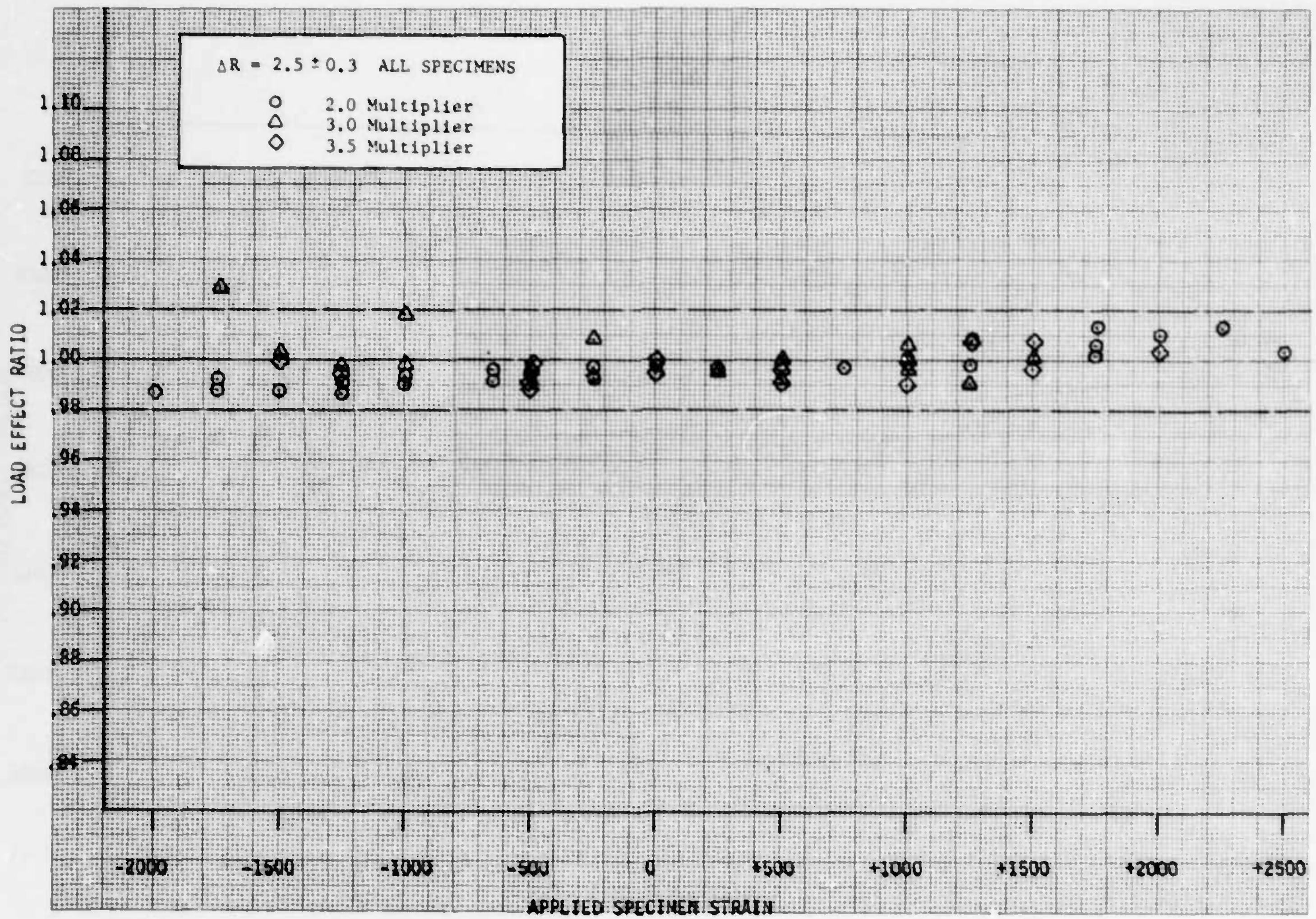

Figure 92 Load Effect Ratio (R=2.5,2.0,3.0,3.5 Multiplier)

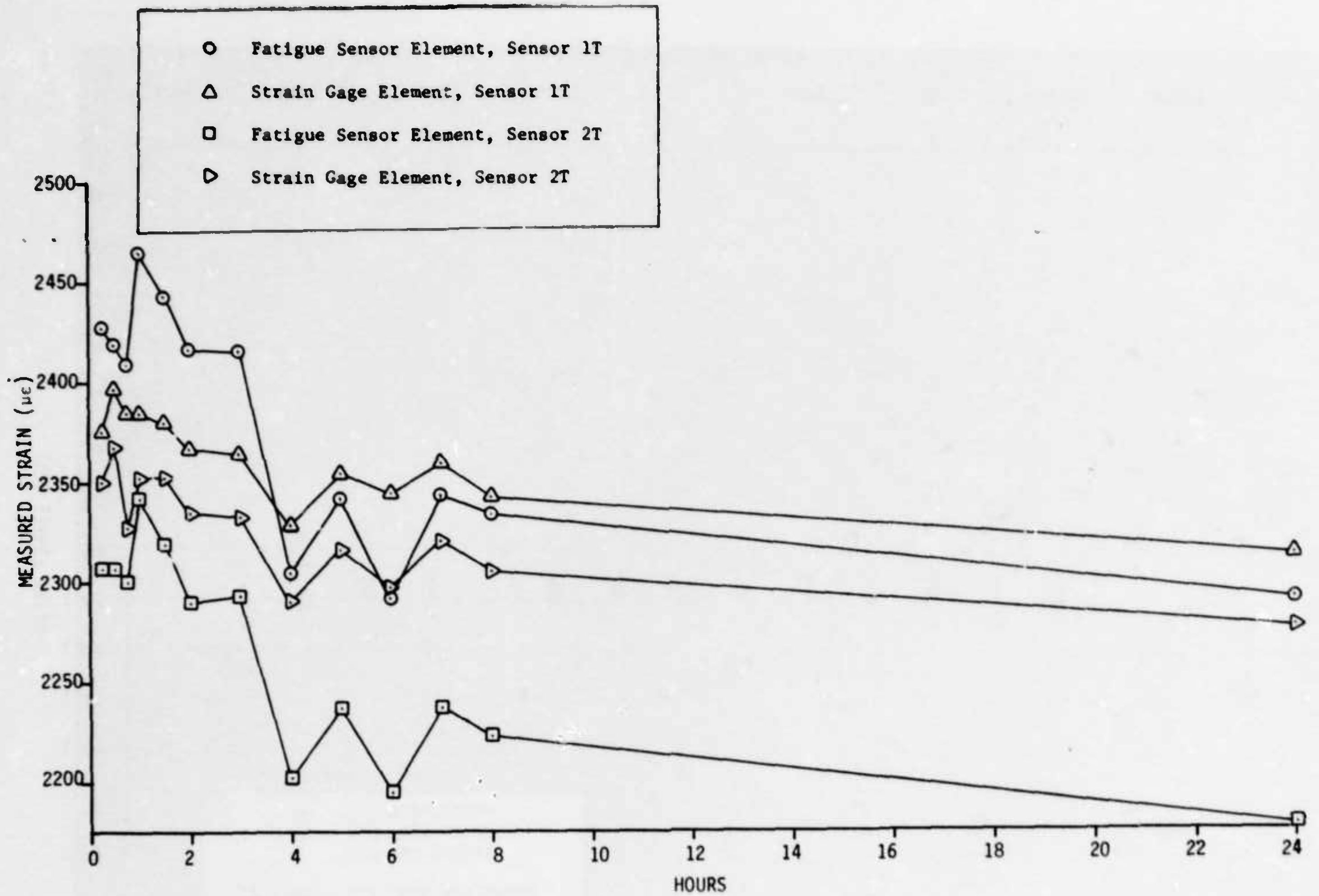

Figure 93 Room Temperature Creep Test Static Load Applied

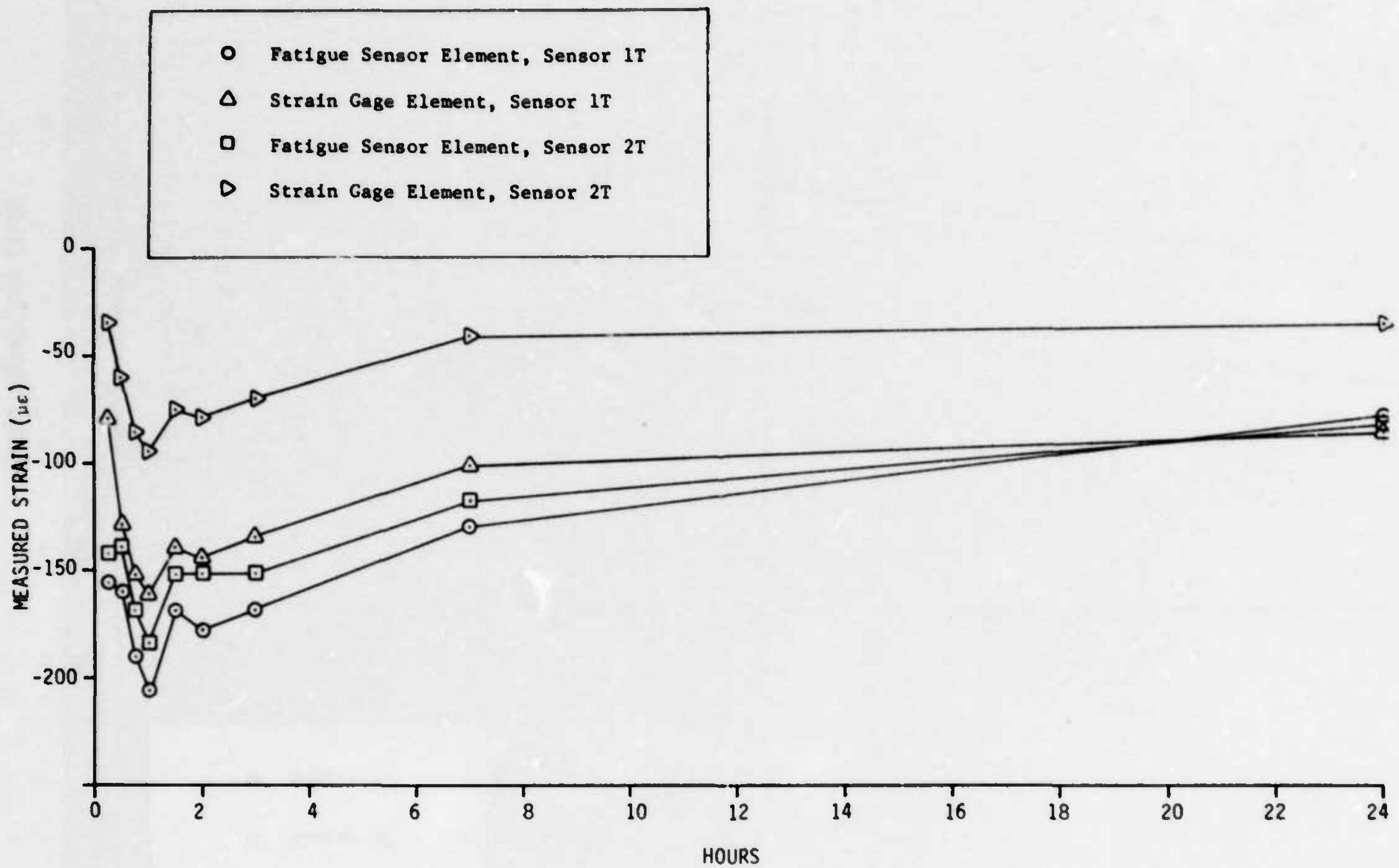

Figure 94 Room Temperature Creep Test Static Load Removed

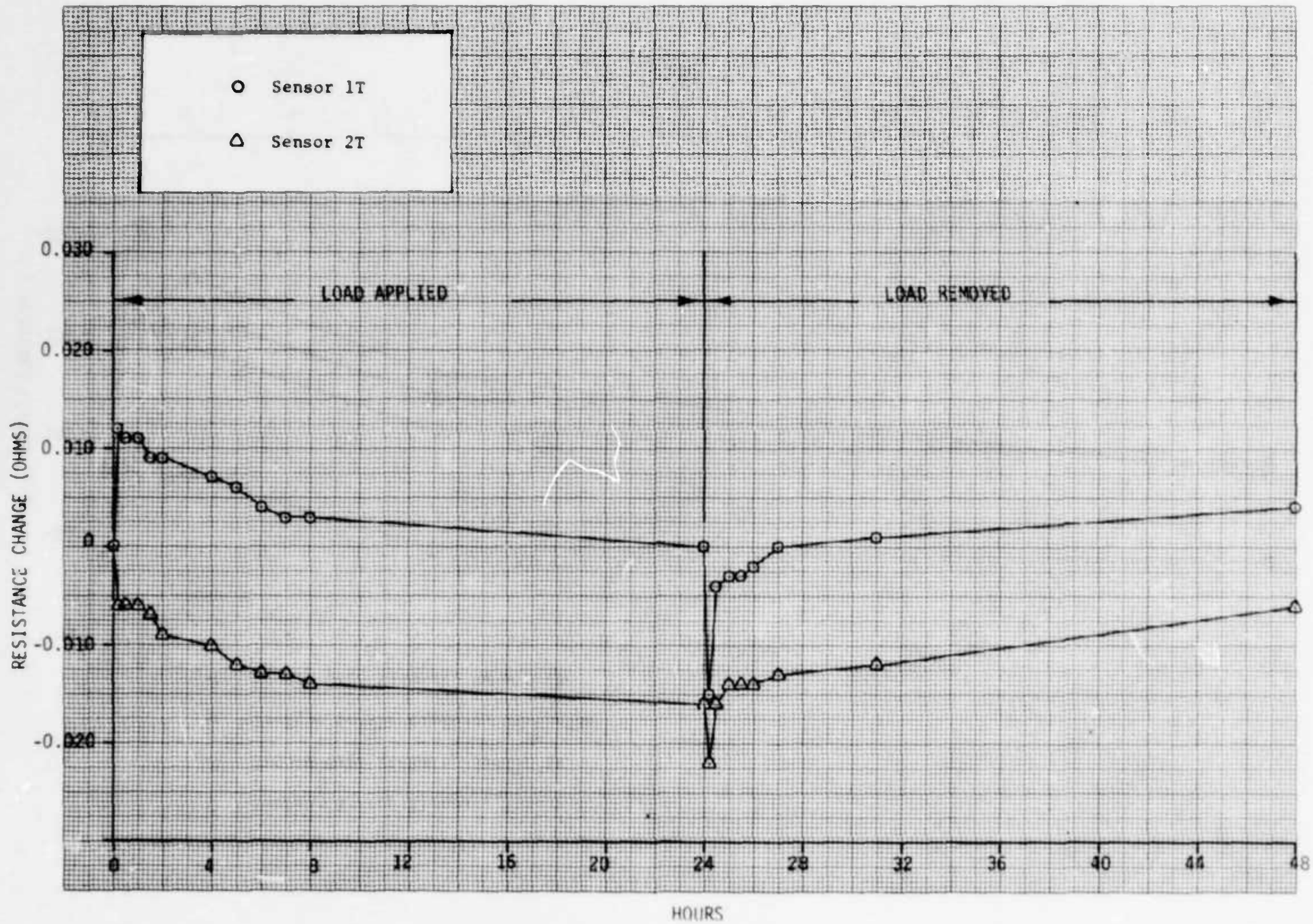

Figure 95 Room Temperature Creep Test Composite FM Sensor Stability

SECTION VIII

COMPRESSIVE CYCLE ELIMINATOR

8.1 INTRODUCTION

A device has been designed by Capt. McIlrath of ASD/ENFSL to eliminate the compressive portion of strain cycles for strain transducers. Per ASD's request, Cessna evaluated the cycle eliminator for applicability to the fatigue sensor. The constant amplitude test series was used to mount the device and study fatigue sensor response.

8.2 EVALUATION

The strain cycle eliminator was installed in three progressive configurations to study adjustment and performance of the device:

a) Mounted on aluminum bar with a conventional strain gage installed as shown by Figure 96. The strain gage was installed on plexiglass to bridge the eliminator "gage" gap.

b) Mounted on constant amplitude specimen #5 with a conventional strain gage installed. A Dentronic elastic multiplier[a] (Reference 3) was used to bridge the eliminator "gage" gap.

c) Mounted on constant amplitude specimen #18 with a FM221-02.5L fatigue sensor installed.

In configuration (a), the adjustment of the cycle eliminator was studied; the plexiglass bridge was found to yield poor strain multiplier performance (multiplier is integral to cycle eliminator design). In configuration (b), the cycle eliminator was tested under cyclic operation with a conventional strain gage installed. The strain gage was hooked to an oscillograph during cycling and results confirmed the compressive portion of the cycle was being eliminated. Adjustment of the device was found to be very sensitive. In configuration (c), an FM fatigue sensor was installed on the cycle eliminator and cycled for 65,000 cycles.

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[a] Dentronic Elastic Multiplier - Multiplier constructed of aluminum shim with elastic center section which amplifies strain with the same basic principle of the Micro-Measurements multiplier.

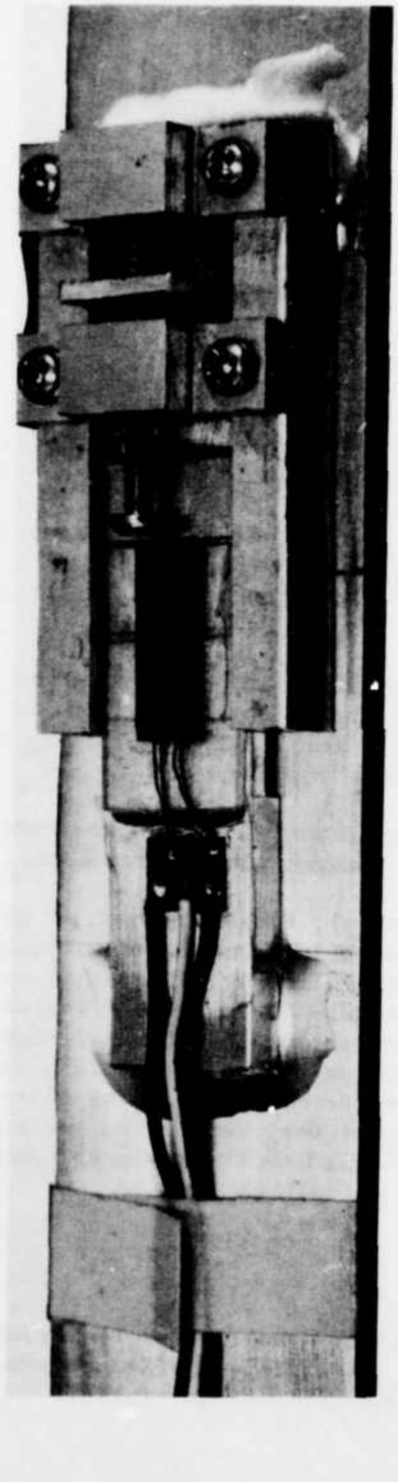

Figure 96 Strain Cycle Eliminator

The fatigue sensor/cycle eliminator installation was made on specimen #18 which was subjected to an alternating strain of ±1500 $\mu\varepsilon$ superimposed on a mean strain of -500 $\mu\varepsilon$ (strain peaks = +1000, -2000 $\mu\varepsilon$). The cycle eliminator operated initially with an effective multiplier of 2.0 which yielded an amplified strain cycle of ±1000 $\mu\varepsilon$ superimposed on a mean strain of +1000 $\mu\varepsilon$ for the tension portion of the specimen strain cycle. The fatigue sensor responded as predicted to the ±1000 $\mu\varepsilon$ applied strain cycle from 0 - 2000 cycles; then the effective multiplier of the strain eliminator began to change from 2.0, drifting higher, until at 65,000 cycles the effective multiplier was approximately 4.2. The fatigue sensor responded in a predictable fashion with increasing response as the multiplier increased. Figure 97 plots fatigue sensor response and the effective multiplier of the cycle eliminator for specimen's #18 data.

The cause of multiplier instability of the cycle eliminator is unknown; the cycle eliminator continued to function in terms of eliminating the compressive portion of the strain cycle for the duration of testing (65,000 cycles).

8.3 RESULTS

a) Compressive strain can be eliminated from strain cycles using the cycle eliminator design.

b) The adjustment of the eliminator as designed is extremely sensitive.

c) Fatigue sensors coupled with the cycle eliminator will respond predictably to only tension cycles.

d) Detail design refinements are required for application. Present cycle eliminator design has extremely sensitive adjustment and lacks stable multiplier performance.

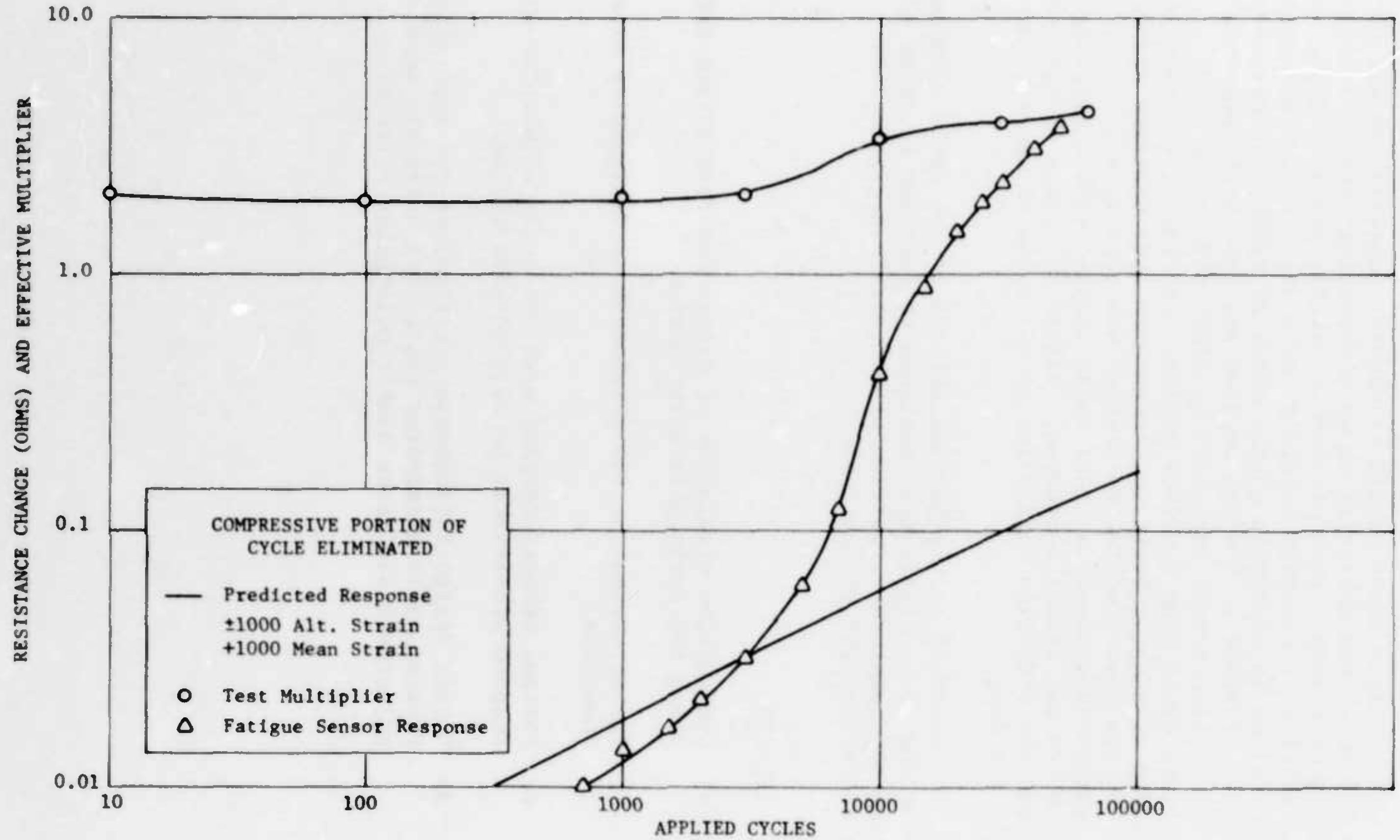

Figure 97 Cycle Eliminator Installed On Specimen #18

SECTION IX

SUMMARY AND RESULTS OF PROGRAM

9.1 STRAIN CYCLE RESPONSE

1. Basic response of fatigue sensor to alternating strain was developed using six constant amplitude specimens (20 levels of amplified alternating strain from ±1000 to ±5250 $\mu\varepsilon$).

2. A family of calibration curves was developed using curve fitting treatment of raw data.

3. Calibration response was slightly higher than indicated by manufacturer's data (Micro-Measurements).

4. Scatter and repeatability of sensor response was approximately ±5%.

5. Normal fatigue sensor failure mode was a rapid upturn of resistance change (ΔR) versus applied cycles occurring at a resistance change of 6-7 ohms.

9.2 MEAN STRAIN RESPONSE

1. Mean strain data was collected using 18 constant amplitude specimens with 17 amplified levels of mean strain ranging from +3500 to -3500 $\mu\varepsilon$.

2. Mean strain effects on fatigue sensor response are significant only during early sensor life (less than 100 cycles) and low alternating strains (less than ±1500 $\mu\varepsilon$ amplified).

3. In general, compressive cycling gives a slightly higher response than tension cycling, subject to the limitations of item 2.

4. Twenty-four fatigue sensors, cycled in pure compression, compare well with 24 sensors, cycled in pure tension, using equal and opposite load cycles.

9.3 SPECTRUM LOAD RESPONSE

1. Two specimens were cycled using 43 identical load levels with the order of application randomly ordered using a series of 34 "flights".

2. The load spectrum was developed using typical A-37 strain cycles taken from scratch gage data at England AFB.

3. Fatigue sensor response is almost identical for both specimens; order of application did not affect sensor response.

4. Response predictions using constant amplitude "calibration" data and NLR cycle count method was consistently below actual response (10-20%).

5. Response versus prediction possibly affected by sensor response to half cycles.

9.4 TEMPERATURE RESPONSE

1. An ambient temperature variation test was performed to develop correction rate data (-65 to 120°F).

2. Approximate linear response from 0° to 120°F gives correction rates of 0 to -0.0015 ohms/°F during the life of 2.5 multiplier fatigue sensor.

3. Four specimens (one each) were cycled under identical constant amplitude strain cycles at +150°, 80°, 0° and -60°F to establish the effect of operational temperatures on FM sensor response.

4. The FM sensor has a limited temperature operating range (-20° to +130°F).

   a) At -60°F effective strain multiplication deteriorates to 1.8 for a 2.5 multiplier.

   b) At +150°F the FM sensor experienced a creep or slippage of the multiplier assembly.

5. The effects of extreme temperatures were found to be reversible, i.e. normal operation resumed by returning to operating range.

6. A temperature induced cycle test (50 cycles from +150° to -50°F) was accomplished to check fatigue sensor stability during temperature cycles (no mechanical strain applied).

7. Unamplified sensors mounted on both aluminum and stainless steel were stable within 0.010 ohms.

8. The temperature induced cycle data is inconclusive due to high temperature creep problems (no resistance change pattern was observed).

9.5 FM MULTIPLIER PERFORMANCE

1. Four multiplier settings were tested (2.0, 2.5, 3.0, 3.5).

2. Multiplier performance was checked by static load cycles at periodic intervals of sensor life.

3. The effective multiplier generally met manufacturer's specified tolerances (±5%) in terms of:

   a) Preset target value.

   b) Repeatability of multiple installations.

   c) Response to varying applied strain levels.

4. The effective multiplier for the 2.5 multiplier was found to be 2.62 ± 0.10 (1221 samples).

5. Effective multiplier performance did not show signs of deterioration and generally exhibited stability for the duration of each test (up to 1,000,000 cycles).

6. Strain compensation produced resistance change readings stable within ±5% for applied strain variations from -2000 to +2500 $\mu\varepsilon$ (when ΔR is above 0.5 ohms).

SECTION X

CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

1. The laboratory program has provided basic performance data for the Micro-Measurements FM fatigue sensor.

2. The fatigue sensor appears to be a useful tool with repeatable and predictable response to strain cycles.

3. The FM fatigue sensor has demonstrated acceptable reliability, accuracy and longevity in this test series.

4. Fatigue sensor response to a wide variety of aircraft loads/environment is known and can be predicted.

5. Test findings indicate the FM multiplier is capable of consistent and reliable strain cycle amplification.

6. The strain gage element of the FM fatigue sensor not only makes the sensor self compensating with respect to residual applied loads but also gives effective temperature compensation.

7. The current FM fatigue sensor/multiplier has two basic limitations:

   a) Limited operational temperature range (-20° to +130°F).

   b) Failure rate is high (15%).

10.2 RECOMMENDATIONS

1. Develop the required methodology for quantitative data treatment of fatigue sensor response using basic performance data derived from foregoing and current fatigue sensor programs.

   a) Investigate a <u>direct</u> relation of sensor response to fatigue damage using S-N data relationship.

b) Investigate an indirect relation of sensor response to fatigue damage using Reference 8 exceedance curve method.

2. Extend FM fatigue sensor operation over a broad temperature range compatible with aircraft operations .

Reference 8. - Sheth, N. J., Bussa, S. L. and Nelson, M. M., Ford Motor Company, "Determination of Accumulated Structural Loads from S-N Gage Resistance Measurements", SAE Paper 730139, 8 January 1973.

APPENDIX A

FATIGUE SENSOR RESPONSE PREDICTION METHOD

A.1 INTRODUCTION

The response of a fatigue sensor to constant amplitude strain cycling can be used as a basis for predicting fatigue sensor response to block cycling with multiple strain levels (Reference 9 , section 5.2). The fatigue sensor response predictions for the spectrum loaded tests (Section V) used this approach and were based on constant amplitude calibration data developed by Section III. A digital computer program developed by Reference 3 program was utilized to make prediction calculations.

A.2 CALIBRATION CURVE

The calibration curves developed by Section III were used for fatigue sensor response predictions (Figure 98). To facilitate computer input, these curves were put into table form using a 704 point straight line approximation. The table was formed to give a discrete value of resistance change for given "cycles" and "alternating strain" (similar to Table 18).

The calibration curves are based on Micro-Measurements FM fatigue sensors subjected to fully reversed constant amplitude strain cycles (zero mean strain). Prediction calculations were not corrected for mean strain effects since these effects were found to be small (Section IV).

A.3 CALCULATION METHOD

The method used to calculate cumulative sensor response to multiple strain level cycling considers the sensor response produced by each individual strain level. The resistance change produced by individual strain levels <u>cannot</u> be added directly due to the non-linear nature of sensor response, but is summed by using equivalent cycles. The calculation process is a four step operation:

Reference 9. - <u>Micro-Measurements S-N Fatigue Life Gage Applications Manual</u>, Second Edition, April 1969.

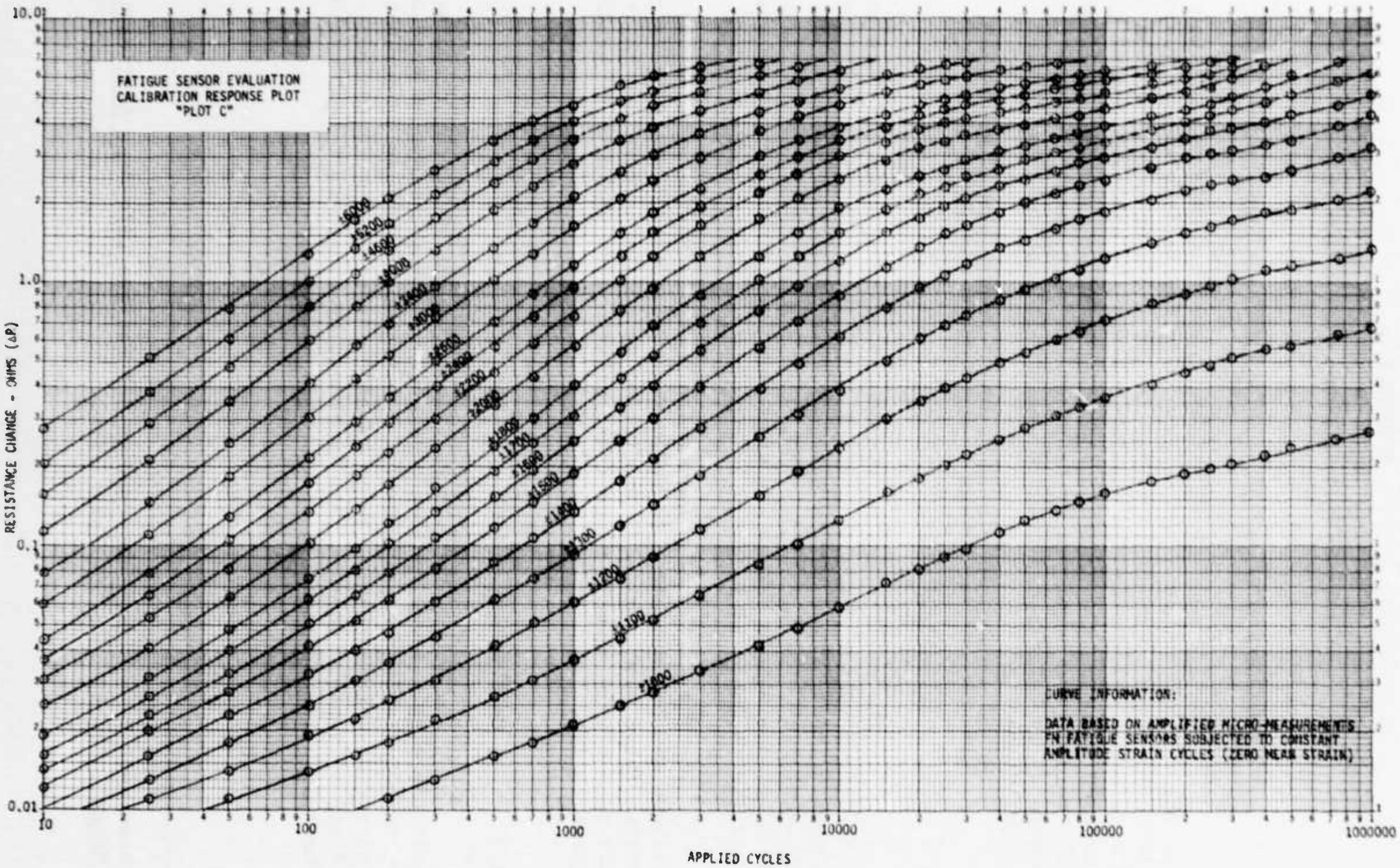

Figure 98 Calibration Data For Prediction Method (Plot "C")

a) Step 1 - Determine value of ΔR (resistance change) for given initial cycles and alternating strain.

b) Step 2 - Determine the "equivalent" cycles required at alternating strain_2 to produce ΔR from Step 1.

c) Step 3 - Add cycle_2 and equivalent cycles to determine new ΔR for alternating strain_2.

d) Step 4 - Determine the "equivalent" cycles required at alternating strain_3 to produce ΔR from Step 3.

Steps 3 and 4 are repeated for cycle_n and alternating strain_n for the complete load spectrum.

A.4 COMPUTER PROGRAM

A computer program was developed by Reference 3 program to take a given set of alternating strains and corresponding applied cycles and calculate the ΔR on a sequential and cumulative basis using the method described by paragraph A.3. The calibration curve (Figure 98) was used as input to the computer program and a logarithmic interpolation feature of the program was used to cover calculations in between table points.

A full description of the computer program and sample calculations are presented by Reference 3.

APPENDIX B

FM FATIGUE SENSOR INSTALLATION PROCEDURE

B.1 INSTALLATION INSTRUCTIONS

The FM fatigue sensor manufacturer (Micro-Measurements) provides instructions for installating the FM sensor (Reference 10). These instructions were followed for the fatigue sensor installations of this program and were found to produce satisfactory results. All fatigue sensors were installed by Cessna instrumentation technicians. M-16 adhesive was used for all installations; heat cure of the adhesive was used for the majority of the installations.

B.2 INSTALLATION TECHNIQUES

The following techniques and procedures have been generated in the process of installing FM fatigue sensors per manufacturer's instructions:

a) A piece of cellophane tape placed across the top of the FM multiplier was used to facilitate handling the sensor and also to hold the sensor in place during bond cure.

b) The M-16 adhesive must be mixed completely. The part A resin was packaged in a small jar for the installations made during this program; special care was required to obtain a complete mix in the jar. Micro-Measurements is reportedly changing the adhesive container design to improve mixing procedure.

c) It is important to fill the recessed multiplier "feet" with adhesive during adhesive application. Voids (air bubbles) in this area can produce defective multiplier performance.

d) Cellophane tape (3M #157) was found to provide adequate clamping pressure on the FM sensor during adhesive cure.

e) The manufacturer's adhesive cure schedule was found to be slightly conservative. A few sensors were installed using a 24 hour room temperature cure; the majority of sensors installed used a heat cure of 140°F for two hours (see Figure 7).

Reference 10. - "FM Series Multiplier and M Bond M-16 Cement Application Instruction", Micro-Measurements Instruction Bulletin B-142, February 1972.

APPENDIX C

STRAIN INDICATOR CALIBRATION FOR FATIGUE SENSOR READING

C.1 INDICATOR CALIBRATION

The Vishay Model P-350 strain indicator was used to read the resistance change of fatigue sensors for all laboratory tests. The indicator gage factor was adjusted to 9.82 to produce a direct reading of ohms electric resistance.

The Vishay indicator was calibrated to read 100 ohm fatigue sensors in a half bridge circuit. The Micro-Measurements FM series fatigue sensor, Model L, is a 100 ohm fatigue sensor/compensating strain gage package which is used to form a half bridge hook up on the Vishay indicator.

The development of a gage factor for direct resistance readings is described by Reference 3. A gage factor of 9.82 was developed to minimize the inherent non-linearity of the indicator bridge circuit. Figure 100 plots a typical calibration check of the Vishay indicator using a precision decade resistor. Indicator reading tolerance using a gage factor of 9.82 is within ±1.5% from 0-7 ohms resistance change.

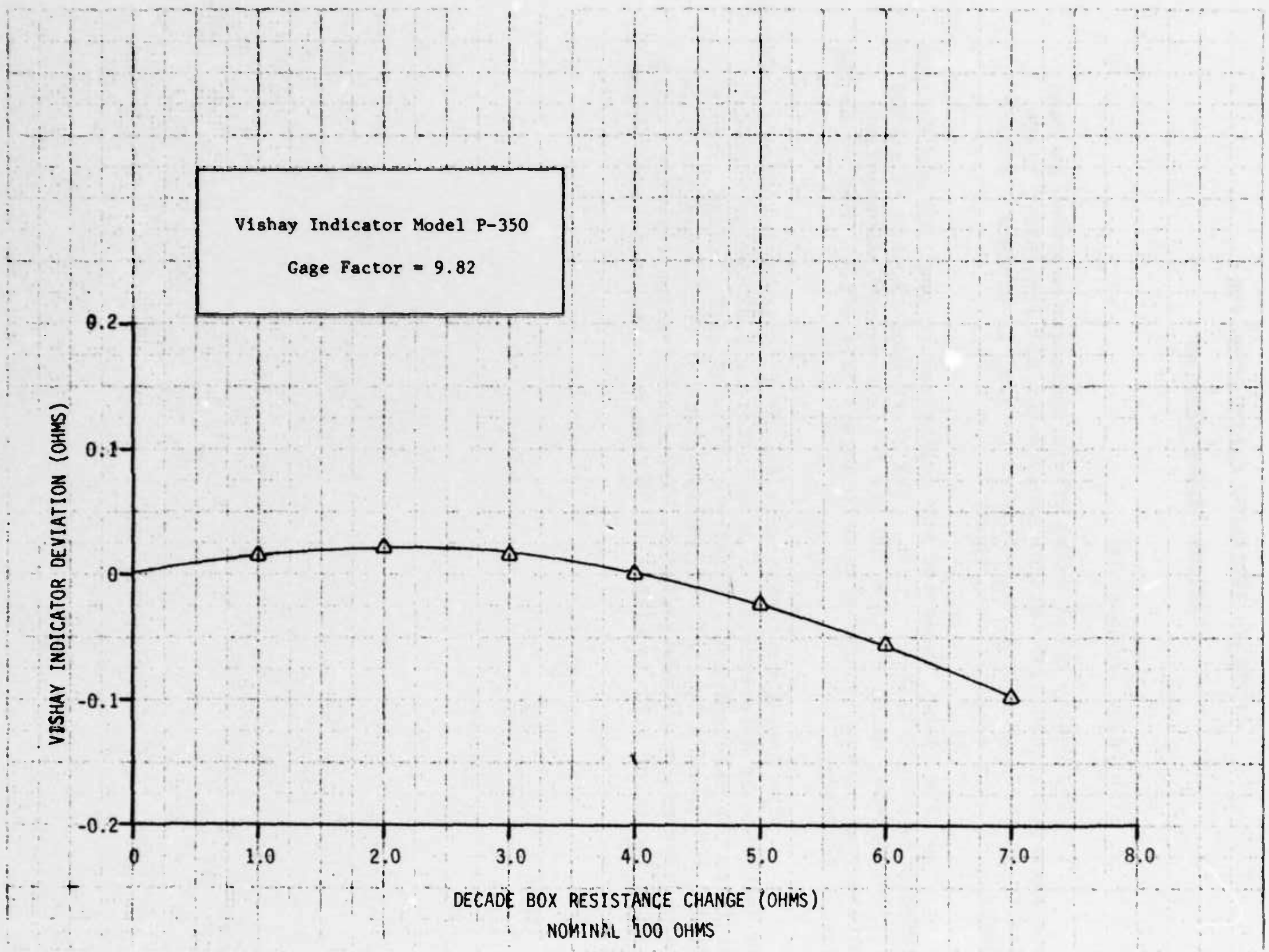

Figure 99 Strain Indicator Calibration

APPENDIX D

LEAST SQUARES CURVE FIT OF RAW TEST DATA (AT 100 CYCLES)

TABLE D-1 SAMPLE CURVE FIT PROGRAM

```
LEAST SQUARES POLYNOMIAL CURVE FIT
EMPERICAL RESISTANCE CHANGE CURVES
SPECIMEN NO. 1 THRU 5 AND NO.33
ZERO MEAN STRAIN AT 100 CYCLES
```

INPUT TEST DATA

POINT NO.	ALT.STRAIN	DELTA R
1	1268.0	0.023
2	1278.0	0.023
3	1315.0	0.028
4	1318.0	0.023
5	1334.0	0.030
6	1538.0	0.040
7	1544.0	0.047
8	1568.0	0.049
9	1694.0	0.063
10	1720.0	0.072
11	1997.0	0.105
12	2028.0	0.098
13	2066.0	0.108
14	2092.0	0.107
15	2298.0	0.159
16	2567.0	0.220
17	2612.0	0.220
18	2666.0	0.216
19	2754.0	0.267
20	2763.0	0.266
21	3047.0	0.327
22	3092.0	0.327
23	3280.0	0.396
24	3338.0	0.363
25	3342.0	0.397
26	3472.0	0.431
27	3933.0	0.598
28	3958.0	0.578
29	4007.0	0.614
30	[illegible]020.0	0.557
31	4336.0	0.661
32	4551.0	0.826
33	5279.0	1.093

TABLE D-1 SAMPLE CURVE FIT PROGRAM (CONTINUED)

NUMBER OF DATA POINTS=33

DEGREE OF POLYNOMIAL=2

DATA POINT	AVE STRAIN	MEASURED DELTA R (OHMS)	EMPERICAL DELTA R (OHMS)	LOG DELTA R DIFFERENCE	SUM OF DIFFERENCE
1	1268.0	0.0230	0.0230	-0.002998	-0.2998E-02
2	1278.0	0.0230	0.0237	-0.030759	-0.3375E-01
3	1315.0	0.0280	0.0262	0.065726	0.3196E-01
4	1318.0	0.0230	0.0264	-0.138943	-0.1069E 00
5	1334.0	0.0300	0.0275	0.084718	-0.2225E-01
6	1538.0	0.0400	0.0446	-0.109977	-0.1322E 00
7	1544.0	0.0470	0.0452	0.038439	-0.9379E-01
8	1568.0	0.0490	0.0475	0.029384	-0.6441E-01
9	1694.0	0.0630	0.0610	0.030880	-0.3352E-01
10	1720.0	0.0720	0.0641	0.116041	0.8251E-01
11	1997.0	0.1050	0.1014	0.034148	0.1166E 00
12	2028.0	0.0980	0.1062	-0.080664	0.3599E-01
13	2066.0	0.1080	0.1122	-0.038335	-0.2339E-02
14	2092.0	0.1070	0.1164	-0.084341	-0.8668E-01
15	2298.0	0.1590	0.1524	0.042201	-0.4447E-01
16	2567.0	0.2200	0.2065	0.063069	0.1859E-01
17	2612.0	0.2200	0.2163	0.016727	0.3531E-01
18	2666.0	0.2160	0.2283	-0.055717	-0.2040E-01
19	2754.0	0.2670	0.2485	0.071452	0.5105E-01
20	2763.0	0.2660	0.2506	0.059252	0.1103E 00
21	3047.0	0.3270	0.3210	0.018407	0.1287E 00
22	3092.0	0.3270	0.3328	-0.017641	0.1110E 00
23	3280.0	0.3960	0.3837	0.031327	0.1423E 00
24	3338.0	0.3630	0.4000	-0.097177	0.4521E-01
25	3342.0	0.3970	0.4011	-0.010465	0.3475E-01
26	3472.0	0.4310	0.4385	-0.017276	0.1747E-01
27	3933.0	0.5980	0.5792	0.031901	0.4937E-01
28	3958.0	0.5780	0.5871	-0.015752	0.3362E-01
29	4007.0	0.6140	0.6028	0.018326	0.5195E-01
30	4020.0	0.5570	0.6070	-0.086006	-0.3405E-01
31	4336.0	0.6610	0.7106	-0.072456	-0.1065E 00
32	4551.0	0.8260	0.7831	0.053233	-0.5327E-01
33	5279.0	1.0930	1.0363	0.053265	-0.1080E-04

EMPERICAL DELTA R EQUATION
EQUATION NO.= 1

LOG DELTA R = -60.23225064 +
12.26573929(LOG STRAIN) +
-0.61069123(LOG STRAIN)(LOG STRAIN)

TABLE D-1 SAMPLE CURVE FIT PROGRAM (CONTINUED)

NUMBER OF DATA POINTS=16

DEGREE OF POLYNOMIAL=2

DATA POINT	AVE STRAIN	MEASURED DELTA R (OHMS)	EMPERICAL DELTA R (OHMS)	LOG DELTA R DIFFERENCE	SUM OF DIFFERENCE
1	1268.0	0.0230	0.0230	-0.002353	-0.2353E-02
2	1278.0	0.0230	0.0236	-0.029796	-0.3215E-01
3	1315.0	0.0280	0.0261	0.067733	0.3558E-01
4	1318.0	0.0230	0.0263	-0.136859	-0.1012E 00
5	1334.0	0.0300	0.0274	0.087187	-0.1408E-01
6	1538.0	0.0400	0.0444	-0.105264	-0.1193E 00
7	1544.0	0.0470	0.0450	0.043155	-0.7619E-01
8	1568.0	0.0490	0.0473	0.034076	-0.4212E-01
9	1694.0	0.0630	0.0608	0.034707	-0.7414E-02
10	1720.0	0.0720	0.0638	0.119550	0.1121E 00
11	1997.0	0.1050	0.1016	0.031974	0.1441E 00
12	2028.0	0.0980	0.1065	-0.083690	0.6042E-01
13	2066.0	0.1080	0.1126	-0.042453	0.1796E-01
14	2092.0	0.1070	0.1169	-0.089235	-0.7126E-01
15	2298.0	0.1590	0.1542	0.030434	-0.4083E-01
16	2567.0	0.2200	0.2111	0.040834	-0.3399E-06

EMPERICAL DELTA R EQUATION
EQUATION NO.= 2

LOG DELTA R = -54.60442616 +
10.73152874(LOG STRAIN) +
-0.50621785(LOG STRAIN)(LOG STRAIN)

TABLE D-1 SAMPLE CURVE FIT PROGRAM (CONTINUED)

NUMBER OF DATA POINTS=12

DEGREE OF POLYNOMIAL=2

DATA POINT	AVE STRAIN	MEASURED DELTA R (OHMS)	EMPERICAL DELTA R (OHMS)	LOG DELTA R DIFFERENCE	SUM OF DIFFERENCE
1	1268.0	0.0230	0.0225	0.018808	0.1880E-01
2	1278.0	0.0230	0.0232	-0.012059	0.6749E-02
3	1315.0	0.0280	0.0260	0.074005	0.8075E-01
4	1316.0	0.0230	0.0262	-0.131437	-0.5068E-01
5	1334.0	0.0300	0.0274	0.088273	0.3759E-01
6	1538.0	0.0400	0.0457	-0.134718	-0.9712E-01
7	1544.0	0.0470	0.0463	0.013398	-0.8372E-01
8	1568.0	0.0490	0.0488	0.003404	-0.8032E-01
9	1694.0	0.0630	0.0626	0.006162	-0.7416E-01
10	1720.0	0.0720	0.0656	0.092747	0.1858E-01
11	1997.0	0.1050	0.1003	0.045280	0.6386E-01
12	2028.0	0.0980	0.1044	-0.063866	-0.5569E-06

EMPERICAL DELTA R EQUATION
EQUATION NO.= 3

LOG DELTA R = -105.66868239 +
24.57568718(LOG STRAIN) +
-1.44397580(LOG STRAIN)(LOG STRAIN)

TABLE D-1 SAMPLE CURVE FIT PROGRAM (CONCLUDED)

```
FINAL CURVE FIT PLOTTING POINTS

ALT. STRAIN =     1000.0  1100.0  1200.0  1300.0  1400.0  1500.0

EQUATION NO. 1    0.0096  0.0137  0.0189  0.0251  0.0325  0.0410
EQUATION NO. 2    0.0097  0.0138  0.0189  0.0251  0.0324  0.0409
EQUATION NO. 3    0.0081  0.0125  0.0180  0.0248  0.0328  0.0420

ALT. STRAIN =     1600.0  1700.0  1800.0  1900.0  2000.0  2100.0

EQUATION NO. 1    0.0508  0.0617  0.0739  0.0873  0.1019  0.1177
EQUATION NO. 2    0.0505  0.0615  0.0737  0.0873  0.1021  0.1183
EQUATION NO. 3    0.0521  0.0633  0.0751  0.0877  0.1007  0.1141

ALT. STRAIN =     2200.0  2300.0  2400.0  2500.0  2600.0  2800.0

EQUATION NO. 1    0.1346  0.1528  0.1720  0.1923  0.2137  0.2594
EQUATION NO. 2    0.1358  0.1546  0.1747  0.1961  0.2188  0.2679
EQUATION NO. 3    0.1276  0.1413  0.1549  0.1684  0.1816  0.2069

ALT. STRAIN =     3000.0  3200.0  3400.0  3600.0  3800.0  4000.0

EQUATION NO. 1    0.3089  0.3617  0.4176  0.4763  0.5374  0.6006
EQUATION NO. 2    0.3219  0.3805  0.4436  0.5109  0.5821  0.6570
EQUATION NO. 3    0.2303  0.2514  0.2700  0.2861  0.2995  0.3104

ALT. STRAIN =     4300.0  4600.0  4900.0  5200.0  5500.0  6000.0

EQUATION NO. 1    0.6986  0.7998  0.9034  1.0084  1.1144  1.2913
EQUATION NO. 2    0.7758  0.9015  1.0334  1.1707  1.3126  1.5578
EQUATION NO. 3    0.3223  0.3293  0.3319  0.3310  0.3270  0.3152
// EOJ
```

Note: Underlined values are final values included in basic Table 18 data.

APPENDIX E

MEAN STRAIN RESPONSE RESISTANCE CHANGE TEST DATA
(Specimen #6 Thru #23)

TABLE E-1 RESISTANCE CHANGE DATA FOR SPECIMEN #6

SPECIMEN NO. = 6

ALT STRAIN = 500 MEAN STRAIN = 1000 ZERO TEMP = 75.5

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.541	-0.304	-0.611	-0.291	-0.996	-0.326

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.2	0.005	0.004	0.005	-0.000	0.008	0.013
2.	25.	76.2	0.009	0.008	0.009	0.000	0.015	0.028
3.	50.	76.2	0.015	0.015	0.015	0.003	0.023	0.045
4.	100.	76.3	0.028	0.030	0.029	0.009	0.043	0.081
5.	150.	77.0	0.038	0.040	0.038	0.011	0.054	0.111
6.	200.	77.0	0.047	0.049	0.048	0.015	0.068	0.137
7.	300.	77.0	0.061	0.064	0.061	0.018	0.087	0.180
8.	500.	77.3	0.083	0.088	0.084	0.024	0.119	0.253
9.	700.	77.3	0.105	0.111	0.106	0.030	0.140	0.323
10.	1000.	77.3	0.134	0.141	0.134	0.038	0.191	0.415
11.	1500.	76.0	0.169	0.180	0.171	0.044	0.246	0.540
12.	2000.	76.0	0.204	0.216	0.206	0.053	0.294	0.654
13.	3000.	76.7	0.267	0.285	0.272	0.066	0.387	0.861
14.	5000.	76.8	0.371	0.399	0.378	0.084	0.540	1.186
15.	7000.	76.8	0.460	0.493	0.470	0.103	0.668	1.444
16.	10000.	76.4	0.567	0.608	0.579	0.119	0.822	1.740
17.	15000.	76.4	0.717	0.767	0.733	0.146	1.032	2.113
18.	20000.	76.4	0.837	0.898	0.857	0.167	1.200	2.387
19.	25000.	76.4	0.937	1.006	0.958	0.189	1.333	2.594
20.	30000.	76.6	1.015	1.092	1.037	0.203	1.439	2.753
21.	40000.	76.6	1.137	1.224	1.163	0.227	1.604	2.999
22.	50000.	76.6	1.235	1.334	1.266	0.251	1.736	3.187
23.	65000.	76.6	1.342	1.452	1.377	0.273	1.879	3.434
24.	80000.	76.6	1.427	1.550	1.468	0.293	1.994	3.719
25.	100000.	77.3	1.524	1.661	1.572	0.317	2.125	4.032
25.	100000.	74.7	1.522	1.660	1.569	0.320	2.116	3.989
26.	150000.	76.3	1.666	1.827	1.724	0.347	2.318	4.357
27.	200000.	77.9	1.754	1.929	1.819	0.363	2.440	4.588
28.	250000.	78.4	1.852	2.043	1.929	0.393	2.572	4.651
29.	300000.	78.2	1.926	2.128	2.012	0.411	2.668	4.716
30.	400000.	78.4	2.081	2.301	2.182	0.452	2.858	4.967
31.	500000.	78.5	2.195	2.430	2.314	0.479	2.995	5.121
32.	750000.	77.2	2.398	2.651	2.589	0.520	3.202	5.354
32.	850000.	77.6	2.480	2.738	2.679	0.537	3.273	5.643
32.	950000.	78.3	2.550	2.810	2.771	0.547	3.324	5.699
33.	1000000.	78.4	2.588	2.847	2.817	0.554	3.350	5.727

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE

TABLE E-2 RESISTANCE CHANGE DATA FOR SPECIMEN #7

SPECIMEN NO. = 7

ALT STRAIN = 750 MEAN STRAIN = 1000 ZERO TEMP = 76.7

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.379	-0.550	-0.462	-0.286	-0.169	-0.185

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	12.	76.7	0.016	0.019	0.014	0.005	0.025	0.049
2.	25.	76.7	0.034	0.036	0.030	0.014	0.049	0.087
3.	50.	76.7	0.060	0.061	0.055	0.025	0.086	0.152
4.	100.	78.5	0.107	0.107	0.099	0.045	0.150	0.258
5.	150.	78.5	0.155	0.153	0.142	0.067	0.215	0.362
6.	200.	78.5	0.188	0.187	0.173	0.082	0.260	0.000
7.	400.	78.5	0.317	0.316	0.296	0.142	0.431	0.000
8.	500.	78.5	0.376	0.373	0.350	0.170	0.506	0.000
9.	700.	77.1	0.483	0.478	0.448	0.222	0.643	0.000
10.	1000.	77.3	0.624	0.620	0.582	0.295	0.821	0.000
11.	1500.	77.3	0.827	0.826	0.774	0.403	1.075	0.000
12.	2000.	77.3	1.007	1.003	0.944	0.499	1.293	0.000
13.	3000.	76.9	1.319	1.316	1.240	0.663	1.667	0.000
14.	5000.	76.9	1.795	1.794	1.699	0.926	2.217	0.000
15.	7000.	75.3	2.121	2.117	2.011	1.112	2.577	0.000
16.	10000.	75.5	0.000	2.492	2.380	1.341	2.988	0.000
17.	15000.	75.5	0.000	2.918	2.798	1.622	3.440	0.000
18.	20000.	74.9	1.388	3.237	3.111	1.856	3.776	0.000
19.	25000.	75.1	1.478	3.491	3.364	2.065	4.048	0.000
20.	30000.	75.1	1.638	3.677	3.548	2.233	4.254	0.000
21.	40000.	78.4	4.500	3.937	3.800	2.497	4.916	0.000
22.	50000.	77.9	5.380	4.147	4.004	2.705	5.094	0.000
23.	65000.	78.7	0.000	4.405	4.254	2.963	5.321	0.000
24.	80000.	78.6	0.000	4.573	4.411	3.122	5.541	0.000
25.	100000.	79.5	0.000	4.756	4.583	3.289	5.762	0.000
26.	150000.	80.1	0.000	5.068	4.893	3.554	5.700	0.000
27.	200000.	78.1	0.000	5.272	5.088	3.716	7.206	0.000
28.	250000.	79.9	0.000	5.410	5.250	3.846	0.000	0.000
29.	300000.	81.1	0.000	5.553	5.352	3.965	0.000	0.000
30.	400000.	83.8	0.000	5.874	5.487	4.213	0.000	0.000
31.	500000.	83.6	0.000	6.111	5.601	4.443	0.000	0.000
31.	550000.	83.6	0.000	6.250	5.667	4.568	0.000	0.000
31.	550000.	76.0	0.000	6.278	5.615	4.597	0.000	0.000
31.	600000.	80.1	0.000	7.032	5.810	4.854	0.000	0.000
32.	750000.	83.0	0.000	7.459	5.950	5.228	0.000	0.000
33.	1000000.	77.4	0.000	8.717	6.180	5.985	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-3 RESISTANCE CHANGE DATA FOR SPECIMEN #8

SPECIMEN NO. =   8

ALT STRAIN = 1000   MEAN STRAIN = 1000   ZERO TEMP = 76.7

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.250	-0.587	-0.510	-0.135	-0.297	-0.401

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	77.3	0.026	0.022	0.028	0.012	0.037	0.066
2.	25.	77.3	0.065	0.057	0.067	0.033	0.089	0.145
3.	50.	77.4	0.120	0.108	0.123	0.064	0.163	0.258
4.	100.	77.6	0.222	0.201	0.223	0.119	0.300	0.459
5.	150.	78.1	0.304	0.274	0.302	0.162	0.408	0.622
6.	200.	78.1	0.377	0.341	0.375	0.201	0.506	0.768
7.	300.	78.1	0.512	0.469	0.513	0.275	0.683	1.026
8.	500.	78.2	0.765	0.704	0.763	0.416	1.010	1.486
9.	700.	78.4	0.974	0.900	0.970	0.538	1.280	1.852
10.	1000.	78.6	1.248	1.156	1.239	0.698	1.627	2.307
11.	1500.	78.5	1.635	1.517	1.619	0.932	2.097	0.000
12.	2000.	78.7	1.954	1.818	1.933	1.136	2.470	0.000
13.	3000.	78.5	2.425	2.272	2.404	1.460	3.002	0.000
14.	5000.	78.3	3.102	2.921	3.062	1.964	3.721	0.000
15.	7000.	78.3	5.082	3.354	3.496	2.331	4.171	0.000
16.	10000.	78.4	0.000	3.798	3.941	2.736	4.618	0.000
17.	15000.	79.0	0.000	4.313	4.455	3.209	5.130	0.000
18.	20000.	78.0	0.000	4.628	4.769	3.523	5.434	0.000
19.	25000.	79.7	0.000	4.864	5.007	3.761	5.664	0.000
20.	30000.	79.3	0.000	5.040	5.184	3.952	5.828	0.000
21.	40000.	80.4	0.000	5.300	5.451	4.230	6.091	0.000
22.	50000.	80.7	0.000	5.480	5.655	4.425	6.267	0.000
23.	65000.	81.2	0.000	5.694	8.743	4.664	6.484	0.000
24.	80000.	81.8	0.000	5.837	9.631	4.827	6.627	0.000
25.	100000.	82.4	0.000	6.019	0.000	5.029	6.805	0.000
25.	100000.	77.3	0.000	5.946	6.351	4.992	6.733	0.000
26.	150000.	80.9	0.000	6.347	0.000	5.418	7.112	0.000
27.	200000.	82.3	0.000	6.499	0.000	5.709	0.000	0.000
28.	250000.	82.0	0.000	6.583	0.000	5.947	0.000	0.000
29.	300000.	84.0	0.000	6.749	0.000	6.157	0.000	0.000
30.	400000.	85.3	0.000	6.887	0.000	6.368	0.000	0.000
31.	500000.	77.6	0.000	6.895	0.000	6.548	0.000	0.000
31.	710000.	84.4	0.000	7.174	0.000	7.078	0.000	0.000
32.	750000.	85.0	0.000	7.226	0.000	7.212	0.000	0.000
33.	1000000.	77.2	0.000	7.224	0.000	7.727	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE

TABLE E-4 RESISTANCE CHANGE DATA FOR SPECIMEN #9

SPECIMEN NO. = 9

ALT STRAIN = 1250 MEAN STRAIN = 1000 ZERO TEMP = 76.9

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.236	-0.238	-0.232	-0.706	-0.201	-0.497

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	77.3	2.741	0.053	0.048	0.025	0.072	0.104
2.	25.	77.2	0.000	0.119	0.117	0.063	0.170	0.230
3.	50.	77.3	0.000	0.215	0.211	0.115	0.309	0.411
4.	100.	77.1	0.000	0.378	0.375	0.205	0.544	0.720
5.	150.	77.0	0.000	0.521	0.520	0.285	0.605	0.986
6.	200.	77.0	0.000	0.648	0.646	0.355	1.961	1.215
7.	300.	77.0	0.000	0.878	0.876	0.483	0.000	1.615
8.	500.	77.9	0.000	1.272	1.266	0.707	0.000	2.252
9.	700.	77.1	0.000	1.601	1.589	0.896	0.000	2.737
11.	1000.	77.3	0.000	2.007	1.991	1.133	0.000	3.279
11.	1500.	77.5	0.000	2.553	2.500	1.470	0.000	0.000
12.	2000.	77.5	0.000	2.978	2.902	1.749	0.000	0.000
13.	3000.	76.6	0.000	3.602	3.491	2.202	0.000	0.000
14.	5000.	78.1	0.000	4.379	4.201	2.619	0.000	0.000
15.	7000.	78.5	0.000	4.859	4.645	3.248	0.000	0.000
16.	10000.	78.6	0.000	5.360	5.096	3.689	0.000	0.000
17.	15000.	79.6	0.000	5.877	0.000	4.187	0.000	0.000
18.	20000.	80.0	0.000	6.186	0.000	4.517	0.000	0.000
19.	25000.	80.5	0.000	6.424	0.000	4.759	0.000	0.000
20.	30000.	80.8	0.000	6.597	0.000	4.945	0.000	0.000
21.	40000.	81.5	0.000	6.947	0.000	5.240	0.000	0.000
22.	50000.	82.4	0.000	7.143	0.000	5.465	0.000	0.000
23.	65000.	82.7	0.000	7.449	0.000	5.716	0.000	0.000
24.	80000.	83.3	0.000	4.369	0.000	5.924	0.000	0.000
25.	100000.	83.5	0.000	0.000	0.000	6.207	0.000	0.000
25.	125000.	84.0	0.000	0.000	0.000	6.454	0.000	0.000
25.	125000.	72.7	0.000	0.000	0.000	6.413	0.000	0.000
26.	150000.	78.5	0.000	0.000	0.000	7.015	0.000	0.000
27.	200000.	82.7	0.000	0.000	0.000	7.401	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-5 RESISTANCE CHANGE DATA FOR SPECIMEN #10

SPECIMEN NO. = 10

ALT STRAIN = 1500 MEAN STRAIN = 1000 ZERO TEMP = 79.4

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.356	-0.158	-0.502	-0.448	-0.285	-0.481

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	77.2	0.080	0.093	0.081	0.030	0.087	0.164
2.	25.	77.2	0.174	0.199	0.181	0.064	0.183	0.470
3.	50.	77.2	0.304	0.343	0.321	0.110	0.321	1.110
4.	100.	76.9	0.523	0.589	0.563	0.186	0.544	3.198
5.	150.	76.9	0.720	0.811	0.781	0.256	0.734	3.868
6.	200.	76.7	0.886	1.001	0.966	0.313	0.891	3.544
7.	300.	76.7	1.181	1.330	1.290	0.417	1.159	6.706
8.	500.	76.7	1.685	1.860	1.820	0.594	1.565	0.000
9.	700.	77.0	2.110	2.269	2.240	0.737	1.846	5.917
10.	1000.	77.0	2.655	2.752	2.749	0.914	2.146	4.898
11.	1500.	77.5	3.367	3.329	3.369	1.135	2.493	0.000
12.	2000.	77.5	3.924	3.755	3.832	1.322	2.751	2.131
13.	3000.	77.9	4.852	4.324	4.476	1.606	3.153	6.319
14.	5000.	79.1	6.513	4.984	5.279	1.999	3.623	2.870
15.	7000.	78.6	8.444	5.303	5.803	2.275	3.918	2.460
16.	10000.	79.6	13.266	5.542	0.000	2.578	4.198	2.330
17.	15000.	80.4	0.000	5.605	0.000	2.935	4.458	3.630
18.	20000.	80.8	0.000	5.453	0.000	3.178	4.631	0.000
19.	25000.	81.1	0.000	5.275	0.000	3.374	4.778	6.753
20.	30000.	83.6	0.000	5.254	0.000	3.533	4.887	7.528
20.	30000.	77.9	0.000	5.221	0.000	3.507	4.846	0.000
21.	40000.	80.7	0.000	5.295	0.000	3.787	5.048	0.000
22.	50000.	82.4	0.000	5.310	0.000	3.957	5.140	0.000
23.	65000.	84.1	0.000	5.270	0.000	4.163	5.286	0.000
23.	75000.	86.5	0.000	5.441	0.000	4.317	5.419	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-6 RESISTANCE CHANGE DATA FOR SPECIMEN #11

SPECIMEN NO. = 11

ALT STRAIN = 500 MEAN STRAIN = -1000 ZERO TEMP = 80.3

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.531	-0.972	-0.513	-0.140	-0.486	-0.492

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	81.8	0.029	0.029	0.027	0.018	0.038	0.039
2.	25.	81.8	0.034	0.036	0.033	0.021	0.048	0.049
3.	50.	81.8	0.040	0.045	0.041	0.025	0.062	0.062
4.	100.	81.1	0.047	0.056	0.053	0.030	0.078	0.084
5.	150.	81.1	0.053	0.067	0.061	0.032	0.094	0.100
6.	200.	81.1	0.061	0.076	0.070	0.036	0.109	0.121
7.	300.	81.1	0.072	0.091	0.083	0.040	0.131	0.155
8.	500.	81.1	0.089	0.114	0.103	0.045	0.168	0.210
9.	700.	81.1	0.109	0.139	0.125	0.053	0.206	0.269
10.	1000.	79.5	0.126	0.165	0.147	0.057	0.249	0.335
11.	1500.	79.4	0.154	0.201	0.179	0.065	0.310	0.437
12.	2000.	79.4	0.179	0.235	0.209	0.073	0.366	0.529
13.	3000.	79.1	0.218	0.289	0.256	0.083	0.460	0.684
14.	5000.	79.1	0.281	0.379	0.336	0.099	0.620	0.928
15.	7000.	79.1	0.331	0.452	0.401	0.111	0.747	1.122
16.	10000.	79.0	0.392	0.547	0.485	0.125	0.909	1.363
17.	15000.	78.7	0.478	0.673	0.600	0.145	1.122	1.665
18.	20000.	78.7	0.554	0.776	0.694	0.162	1.292	1.889
19.	25000.	79.2	0.616	0.864	0.774	0.175	1.435	2.066
20.	30000.	79.2	0.670	0.943	0.845	0.189	1.560	2.213
20.	30000.	77.4	0.663	0.925	0.834	0.188	1.541	2.175
21.	40000.	76.9	0.756	1.066	0.954	0.205	1.744	2.445
22.	50000.	77.1	0.828	1.163	1.051	0.220	1.903	2.632
23.	65000.	77.5	0.918	1.292	1.167	0.237	2.087	2.848
24.	80000.	77.8	0.991	1.405	1.263	0.253	2.236	3.006
25.	100000.	77.8	1.082	1.548	1.380	0.276	2.409	3.179
26.	150000.	78.0	1.377	1.974	1.749	0.348	2.893	3.654
27.	200000.	78.6	1.518	2.214	1.926	0.390	3.118	3.874
28.	250000.	78.7	1.581	2.331	2.009	0.405	3.236	4.000
29.	300000.	79.7	1.634	2.539	2.078	0.421	3.337	4.113
30.	400000.	78.9	1.723	7.558	2.188	0.442	3.507	4.326
31.	500000.	77.9	1.790	0.000	2.274	0.463	3.644	4.491
32.	750000.	79.6	1.956	0.000	2.476	0.489	3.993	5.125
33.	1000000.	78.8	2.087	0.000	2.623	0.513	4.295	5.657

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-7 RESISTANCE CHANGE DATA FOR SPECIMEN #12

SPECIMEN NO. = 12

ALT STRAIN = 750 MEAN STRAIN = -1000 ZERO TEMP = 74.5

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.207	-0.431	-0.597	-0.570	-0.508	-0.498

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	75.4	0.043	0.038	0.040	0.021	0.053	0.085
2.	25.	75.4	0.063	0.057	0.059	0.030	0.078	0.124
3.	50.	75.4	0.088	0.083	0.084	0.042	0.111	0.176
4.	100.	74.9	0.132	0.127	0.126	0.059	0.176	0.265
5.	150.	74.5	0.173	0.167	0.166	0.077	0.232	0.349
6.	200.	74.5	0.210	0.202	0.200	0.091	0.283	0.420
7.	300.	74.5	0.277	0.268	0.263	0.118	0.378	0.552
8.	500.	75.2	0.386	0.377	0.369	0.161	0.553	0.770
9.	700.	75.2	0.479	0.473	0.459	0.196	0.691	0.955
10.	1000.	75.2	0.613	0.608	0.592	0.252	0.891	1.208
11.	1500.	75.1	0.801	0.798	0.777	0.329	1.163	1.554
12.	2000.	75.1	0.957	0.966	0.939	0.398	1.400	1.848
13.	3000.	76.4	1.251	1.253	1.215	0.519	1.793	2.321
14.	5000.	76.4	1.695	1.699	1.649	0.727	2.369	2.987
15.	7000.	76.3	2.025	2.031	1.976	0.894	2.756	3.427
16.	10000.	76.0	2.408	2.417	2.362	1.104	3.157	3.898
17.	15000.	76.3	2.842	2.838	2.794	1.357	3.647	4.386
18.	20000.	76.3	3.149	3.139	3.107	1.555	3.947	4.710
19.	25000.	76.3	3.390	3.371	3.354	1.718	4.184	4.955
20.	30000.	76.5	3.581	3.550	3.554	1.855	4.388	5.139
21.	40000.	76.6	3.869	3.809	3.851	2.065	4.674	5.416
22.	50000.	76.6	4.117	4.041	4.113	2.256	4.928	5.666
23.	65000.	76.6	4.396	4.298	4.411	2.476	5.405	5.967
24.	82400.	78.3	4.634	4.507	4.663	2.667	5.744	6.221
24.	99800.	76.8	4.802	4.636	4.838	2.799	6.108	6.409
25.	100000.	76.0	4.802	4.629	4.846	2.796	6.610	6.417
26.	150000.	77.2	5.366	5.071	5.479	3.126	6.862	7.462
27.	200000.	77.9	5.747	5.334	5.918	3.390	7.458	8.918
28.	250000.	78.8	6.045	5.530	6.263	3.696	9.143	0.000
29.	300000.	79.0	6.322	5.712	6.614	4.035	0.000	0.000
30.	400000.	79.2	6.979	6.161	7.415	0.000	0.000	0.000
31.	500000.	78.1	7.697	6.568	8.281	0.000	0.000	0.000
31.	550000.	78.3	8.263	6.931	9.119	0.000	0.000	0.000
31.	600000.	79.1	8.737	7.229	9.761	0.000	0.000	0.000
31.	650000.	79.5	9.357	7.526	10.332	0.000	0.000	0.000
31.	700000.	81.1	10.199	7.892	0.000	0.000	0.000	0.000
31.	710000.	79.8	0.000	8.018	0.000	0.000	0.000	0.000
32.	750000.	79.9	0.000	8.336	0.000	0.000	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE

TABLE E-8 RESISTANCE CHANGE DATA FOR SPECIMEN #13

SPECIMEN NO. = 13

ALT STRAIN = 1000 MEAN STRAIN = -1000 ZERO TEMP = 76.7

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.363	-0.395	-0.154	-0.207	-0.432	-0.289

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
0.	1.	76.6	0.041	0.053	0.033	0.024	0.045	0.051
1.	15.	76.2	0.095	0.079	0.092	0.046	0.119	0.165
2.	25.	76.2	0.123	0.109	0.120	0.057	0.156	0.212
3.	50.	76.2	0.181	0.152	0.177	0.080	0.231	0.313
4.	100.	76.5	0.277	0.222	0.272	0.124	0.361	0.482
5.	150.	76.4	0.363	0.274	0.356	0.162	0.476	0.629
6.	200.	76.4	0.439	0.346	0.430	0.196	0.576	0.760
7.	300.	76.4	0.578	0.480	0.563	0.260	0.757	0.991
8.	500.	76.4	0.816	0.694	0.796	0.369	1.070	1.388
9.	700.	76.4	1.019	0.876	0.996	0.466	1.336	1.714
10.	1000.	76.8	1.288	1.131	1.258	0.596	1.678	2.123
11.	1500.	76.2	1.656	1.469	1.639	0.784	2.139	2.652
12.	2000.	76.2	1.964	1.764	1.925	0.950	2.513	3.061
13.	3000.	76.8	2.459	2.240	2.412	1.241	3.099	3.665
14.	5000.	77.2	3.135	2.885	3.074	1.691	3.825	4.406
15.	7000.	77.2	3.596	3.329	3.521	2.038	4.294	4.887
16.	10000.	77.5	4.065	3.773	3.968	2.429	4.747	5.352
17.	15000.	77.2	4.606	4.301	4.482	2.902	5.278	5.935
18.	20000.	77.2	4.943	4.635	4.792	3.223	5.594	6.299
19.	25000.	77.2	5.195	4.907	5.024	3.466	5.832	6.612
20.	30000.	78.3	5.380	5.103	5.189	3.655	6.000	6.871
20.	30000.	76.5	5.316	5.037	5.118	3.618	5.926	6.783
21.	40000.	76.8	5.757	5.508	5.467	3.966	6.323	7.609
22.	50000.	76.8	6.053	5.961	5.691	4.229	6.577	8.455
23.	65000.	78.3	6.403	6.376	5.944	4.558	6.949	0.000
24.	80000.	78.8	6.666	6.684	6.102	4.862	7.479	0.000
25.	100000.	80.0	7.025	7.040	6.293	5.375	8.833	0.000
26.	150000.	80.4	7.956	7.851	6.758	0.000	0.000	0.000
26.	175000.	81.0	8.540	8.131	7.077	0.000	0.000	0.000
27.	200000.	81.1	9.227	8.918	7.390	0.000	0.000	0.000
27.	225000.	81.9	9.973	9.290	7.826	0.000	0.000	0.000
28.	250000.	80.7	0.000	9.865	8.594	0.000	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-9 RESISTANCE CHANGE DATA FOR SPECIMEN #14

SPECIMEN NO. = 14

ALT STRAIN = 500 MEAN STRAIN = -500 ZERO TEMP = 75.5

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.284	-0.563	-0.142	-0.382	-0.658	-0.814

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.2	0.018	0.020	0.016	0.006	0.026	0.035
2.	25.	76.2	0.024	0.026	0.020	0.008	0.035	0.049
3.	50.	76.2	0.028	0.031	0.027	0.010	0.045	0.065
4.	100.	76.6	0.036	0.041	0.036	0.013	0.060	0.093
5.	150.	76.7	0.042	0.047	0.041	0.012	0.073	0.117
6.	200.	76.7	0.045	0.051	0.045	0.012	0.083	0.136
7.	300.	76.7	0.057	0.065	0.057	0.016	0.105	0.177
8.	500.	76.7	0.072	0.083	0.075	0.019	0.141	0.245
9.	700.	76.9	0.088	0.103	0.094	0.023	0.177	0.311
10.	1000.	76.9	0.108	0.129	0.117	0.026	0.224	0.398
11.	1500.	77.4	0.134	0.160	0.149	0.030	0.284	0.515
12.	2000.	77.4	0.154	0.187	0.174	0.033	0.337	0.616
13.	3000.	77.4	0.189	0.233	0.218	0.040	0.428	0.790
14.	5000.	77.4	0.251	0.312	0.289	0.048	0.582	1.078
15.	7000.	77.6	0.304	0.380	0.352	0.052	0.717	1.309
16.	10000.	78.1	0.378	0.473	0.438	0.064	0.891	1.597
17.	15000.	78.1	0.474	0.597	0.550	0.074	1.117	1.953
18.	20000.	78.1	0.556	0.700	0.647	0.083	1.299	2.221
19.	25000.	78.1	0.626	0.786	0.728	0.091	1.451	2.431
20.	30000.	78.8	0.686	0.858	0.797	0.097	1.575	2.600
21.	40000.	79.5	0.793	0.981	0.915	0.112	1.778	2.858
22.	50000.	79.5	0.879	1.081	1.012	0.122	1.942	3.055
23.	65000.	80.0	0.983	1.198	1.127	0.134	2.131	3.276
24.	80000.	80.0	1.068	1.292	1.217	0.145	2.279	3.445
25.	100000.	80.9	1.162	1.397	1.318	0.159	2.439	3.622
26.	150000.	78.6	1.297	1.542	1.460	0.177	2.669	3.862
27.	200000.	79.2	1.496	1.746	1.668	0.207	2.956	4.185
28.	250000.	79.8	1.638	1.883	1.803	0.233	3.148	4.374
29.	300000.	80.0	1.733	1.976	1.897	0.246	3.287	4.512
30.	400000.	80.6	1.865	2.102	2.022	0.266	3.495	4.713
31.	500000.	81.0	1.957	2.187	2.105	0.278	3.658	4.882
32.	750000.	79.8	2.154	2.377	2.292	0.297	4.029	5.233
33.	1000000.	79.6	2.414	2.626	2.543	0.324	4.522	5.747

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE

TABLE E-10 RESISTANCE CHANGE DATA FOR SPECIMEN #15

SPECIMEN NO. = 15

ALT STRAIN = 750 MEAN STRAIN = -500 ZERO TEMP = 76.9

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.016	-0.524	-0.580	-0.367	-0.825	-0.017

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.6	0.025	0.027	0.031	0.018	0.034	0.083
2.	25.	76.6	0.037	0.041	0.047	0.024	0.060	0.116
3.	50.	76.6	0.061	0.063	0.069	0.034	0.098	0.175
4.	100.	76.5	0.097	0.100	0.107	0.049	0.164	0.277
5.	150.	76.5	0.131	0.134	0.143	0.065	0.223	0.368
6.	200.	76.5	0.160	0.162	0.173	0.076	0.275	0.446
7.	300.	76.5	0.215	0.218	0.231	0.101	0.372	0.591
8.	500.	76.5	0.313	0.313	0.327	0.142	0.540	0.842
9.	700.	76.5	0.397	0.395	0.414	0.176	0.686	1.056
10.	1000.	76.8	0.501	0.499	0.519	0.218	0.869	1.315
11.	1500.	77.1	0.660	0.659	0.685	0.283	1.136	1.689
12.	2000.	77.1	0.806	0.802	0.834	0.343	1.370	2.007
13.	3000.	77.2	1.053	1.044	1.082	0.451	1.753	2.505
14.	5000.	77.2	1.448	1.436	1.484	0.631	2.323	3.186
15.	7000.	77.2	1.756	1.740	1.794	0.778	2.726	3.634
16.	10000.	76.9	2.116	2.102	2.162	0.967	3.165	4.097
17.	15000.	77.0	2.555	2.543	2.612	1.216	3.670	4.604
18.	20000.	77.0	2.870	2.860	2.934	1.413	4.007	4.933
19.	25000.	77.0	3.112	3.104	3.186	1.573	4.260	5.181
20.	30000.	77.2	3.304	3.296	3.382	1.707	4.452	5.366
21.	40000.	77.4	3.588	3.572	3.672	1.911	4.739	5.635
22.	50000.	77.4	3.827	3.786	3.899	2.075	4.965	5.858
23.	65000.	77.7	4.118	4.014	4.143	2.261	5.212	6.092
23.	65000.	75.6	4.091	3.985	4.118	2.245	5.170	6.038
24.	80000.	75.6	4.412	4.168	4.340	2.373	5.425	6.304
25.	100000.	75.7	5.026	4.372	4.592	2.529	5.727	6.572
26.	150000.	76.6	6.307	4.726	5.052	2.793	6.343	7.253
27.	200000.	78.0	7.032	4.948	5.345	2.962	6.827	8.183
28.	250000.	77.7	0.000	5.173	5.644	3.139	7.489	0.000
29.	300000.	77.7	0.000	5.349	5.896	3.277	9.418	0.000
29.	350000.	77.5	0.000	5.522	6.166	3.391	0.000	0.000
29.	350000.	71.2	0.000	5.501	6.171	3.369	0.000	0.000
30.	400000.	76.7	0.000	5.864	6.911	3.539	0.000	0.000
31.	500000.	79.1	0.000	6.381	8.047	3.809	0.000	0.000
32.	740000.	80.7	0.000	7.592	0.000	4.324	0.000	0.000
33.	1000000.	80.7	0.000	0.000	0.000	4.898	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE

TABLE E-11 RESISTANCE CHANGE DATA FOR SPECIMEN #16

SPECIMEN NO. = 16

ALT STRAIN = 1000   MEAN STRAIN = -500   ZERO TEMP = 78.5

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.273	-0.374	-0.656	-0.298	-0.197	-0.454

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	78.9	0.059	0.060	0.062	0.034	0.068	0.096
2.	25.	78.9	0.102	0.100	0.108	0.057	0.127	0.179
3.	50.	78.9	0.164	0.158	0.172	0.088	0.214	0.300
4.	100.	78.8	0.270	0.258	0.284	0.146	0.355	0.511
5.	150.	78.8	0.357	0.339	0.370	0.192	0.473	0.680
6.	250.	78.8	0.497	0.473	0.516	0.265	0.659	0.952
7.	300.	78.8	0.562	0.534	0.583	0.299	0.743	1.072
8.	500.	78.8	0.792	0.750	0.826	0.424	1.047	1.504
9.	700.	78.8	0.990	0.938	1.030	0.531	1.301	1.852
10.	1000.	78.5	1.250	1.184	1.296	0.673	1.629	2.286
11.	1500.	78.5	1.612	1.529	1.670	0.879	2.076	2.843
12.	2000.	78.5	1.917	1.822	1.982	1.062	2.437	3.276
13.	3000.	78.2	2.403	2.293	2.481	1.371	2.991	3.898
14.	5000.	78.2	3.076	2.956	3.178	1.855	3.716	4.650
15.	7000.	78.2	3.515	3.401	3.643	2.213	4.183	5.097
16.	10000.	78.1	3.976	3.881	4.137	2.621	4.667	5.589
17.	15000.	78.1	4.486	4.437	4.695	3.104	5.226	6.184
18.	20000.	78.1	4.850	4.887	5.105	3.455	5.648	6.811
19.	25000.	78.4	5.083	5.232	5.381	3.705	5.922	0.000
19.	25000.	76.2	5.030	5.182	5.334	3.672	5.863	0.000
20.	30000.	76.3	5.253	5.550	5.618	3.893	6.247	0.000
21.	40000.	76.6	5.590	6.433	6.067	4.265	6.781	0.000
22.	50000.	77.2	5.824	7.266	6.396	4.536	7.254	0.000
23.	65000.	77.8	6.075	8.340	6.789	4.813	8.019	0.000
24.	80000.	78.3	6.289	9.512	7.105	5.045	9.622	0.000
25.	100000.	78.7	6.544	0.000	7.546	5.276	0.000	0.000
26.	150000.	80.4	7.300	0.000	8.984	5.811	0.000	0.000
26.	175000.	81.0	7.936	0.000	9.867	6.038	0.000	0.000
27.	200000.	80.2	8.653	0.000	0.000	6.297	0.000	0.000
27.	225000.	81.0	9.684	0.000	0.000	6.530	0.000	0.000
28.	250000.	77.9	0.000	0.000	0.000	6.751	0.000	0.000
29.	300000.	80.1	0.000	0.000	0.000	7.460	0.000	0.000
30.	400000.	80.3	0.000	0.000	0.000	8.818	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-12 RESISTANCE CHANGE DATA FOR SPECIMEN #17

SPECIMEN NO. = 17

ALT STRAIN = 1250 MEAN STRAIN = -500 ZERO TEMP = 75.7

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.391	-0.306	-0.799	-0.934	-1.141	-0.473

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	75.6	0.082	0.073	0.076	0.046	0.127	0.164
2.	25.	75.6	0.149	0.134	0.138	0.082	0.227	0.298
3.	50.	75.7	0.251	0.231	0.232	0.140	0.377	0.498
4.	100.	75.7	0.419	0.388	0.384	0.233	0.626	0.823
5.	150.	76.1	0.567	0.528	0.521	0.318	0.847	1.102
6.	200.	76.1	0.697	0.651	0.645	0.394	1.043	1.345
7.	300.	76.1	0.927	0.867	0.860	0.526	1.384	1.754
8.	500.	76.1	1.327	1.240	1.229	0.760	1.942	2.411
9.	700.	76.1	1.665	1.555	1.539	0.969	2.389	2.916
10.	1000.	76.5	2.095	1.949	1.930	1.237	2.921	3.495
11.	1500.	76.5	2.667	2.472	2.447	1.608	3.569	4.191
12.	2000.	76.5	3.116	2.874	2.849	1.915	4.029	4.673
13.	3000.	76.4	3.813	3.486	3.457	2.414	4.689	5.373
14.	5000.	76.4	4.767	4.246	4.219	3.090	5.474	6.242
15.	7000.	76.4	5.432	4.734	4.705	3.551	6.019	6.843
16.	10000.	77.0	6.182	5.239	5.194	4.025	0.000	7.697
17.	15000.	77.0	7.237	5.813	5.752	4.553	0.000	9.122
18.	20000.	77.0	8.074	6.170	6.092	4.878	0.000	0.000
19.	25000.	78.0	8.848	6.450	6.366	5.126	0.000	0.000
20.	30000.	78.6	9.632	6.711	6.607	5.324	0.000	0.000
20.	30000.	76.1	9.659	6.639	6.538	5.271	0.000	0.000
21.	40000.	77.3	0.000	7.330	7.186	5.654	0.000	0.000
22.	50000.	78.3	0.000	7.822	7.749	5.935	0.000	0.000
23.	65000.	79.5	0.000	8.592	8.834	6.256	0.000	0.000
24.	80000.	79.9	0.000	9.671	0.000	6.526	0.000	0.000
25.	100000.	81.4	0.000	0.000	0.000	6.860	0.000	0.000
26.	150000.	82.1	0.000	0.000	0.000	7.735	0.000	0.000
27.	200000.	82.5	0.000	0.000	0.000	8.715	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-13 RESISTANCE CHANGE DATA FOR SPECIMEN #18

SPECIMEN NO. = 18

ALT STRAIN = 1500 MEAN STRAIN = -500 ZERO TEMP = 76.0

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.229	-0.459	-0.391	-0.235	-0.326	0.195

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	75.9	0.128	0.120	0.109	0.069	0.170	0.237
2.	25.	76.0	0.238	0.217	0.202	0.126	0.310	0.409
3.	50.	75.8	0.389	0.355	0.332	0.204	0.517	0.654
4.	100.	76.1	0.645	0.593	0.561	0.342	0.866	1.061
5.	150.	76.1	0.868	0.797	0.755	0.461	1.167	1.407
6.	200.	76.1	1.069	0.982	0.931	0.570	1.430	1.710
7.	300.	76.2	1.423	1.304	1.240	0.762	1.880	2.217
8.	500.	76.0	2.016	1.835	1.750	1.092	2.579	2.996
9.	700.	76.2	2.495	2.264	2.165	1.367	3.104	3.570
10.	1000.	76.2	3.077	2.774	2.660	1.715	3.709	4.212
11.	1500.	76.3	3.834	3.399	3.268	2.171	4.810	4.950
12.	2000.	76.3	4.429	3.859	3.718	2.535	0.000	5.484
13.	3000.	76.7	5.363	4.509	4.355	3.093	0.000	6.206
14.	5000.	76.7	6.834	5.297	5.117	3.788	0.000	7.189
15.	7000.	76.7	7.922	5.796	5.595	4.242	0.000	8.013
16.	10000.	77.5	9.516	6.339	6.089	4.703	0.000	0.000
17.	15000.	78.4	0.000	7.057	6.685	5.244	0.000	0.000
18.	20000.	78.4	0.000	7.611	7.107	5.597	0.000	0.000
19.	25000.	78.4	0.000	8.148	7.473	5.857	0.000	0.000
20.	30000.	79.2	0.000	8.687	7.807	6.069	0.000	0.000
21.	40000.	78.5	0.000	0.000	0.000	6.684	0.000	0.000
22.	50000.	79.3	0.000	0.000	0.000	0.000	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-14 RESISTANCE CHANGE DATA FOR SPECIMEN #19

SPECIMEN NO. = 19

ALT STRAIN = 500 MEAN STRAIN = 500 ZERO TEMP = 76.7

INTIAL ZERO READING*	1U	2M	3L	4U	5M	6L
	-0.506	-0.492	-0.587	-0.428	-0.712	-0.414

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	77.0	0.006	0.004	0.005	0.004	0.008	0.012
2.	25.	77.0	0.009	0.007	0.009	0.004	0.014	0.024
3.	50.	77.[illegible]	0.014	0.012	0.014	0.005	0.025	0.044
4.	100.	77.6	0.021	0.018	0.020	0.006	0.040	0.073
5.	150.	77.0	0.026	0.022	0.025	0.006	0.053	0.096
6.	200.	77.0	0.032	0.028	0.031	0.007	0.066	0.120
7.	300.	77.0	0.044	0.038	0.041	0.009	0.090	0.164
8.	500.	77.0	0.062	0.056	0.061	0.012	0.131	0.242
9.	700.	77.0	0.081	0.072	0.077	0.014	0.170	0.312
10.	1000.	76.7	0.104	0.092	0.098	0.018	0.220	0.407
11.	1500.	76.7	0.139	0.122	0.130	0.022	0.294	0.544
12.	2000.	76.7	0.169	0.149	0.159	0.024	0.361	0.667
13.	3000.	76.4	0.224	0.195	0.210	0.030	0.481	0.879
14.	5000.	76.5	0.320	0.275	0.298	0.038	0.685	1.222
15.	7000.	76.4	0.404	0.350	0.377	0.047	0.857	1.491
16.	10000.	76.6	0.509	0.437	0.474	0.056	1.062	1.801
17.	15000.	76.6	0.647	0.558	0.606	0.066	1.324	2.179
18.	20000.	76.6	0.757	0.654	0.711	0.079	1.526	2.451
19.	25000.	76.2	0.845	0.732	0.798	0.086	1.687	2.659
19.	25000.	74.3	0.845	0.732	0.798	0.090	1.677	2.641
20.	30000.	73.6	0.931	0.809	0.882	0.099	1.820	2.821
21.	40000.	76.2	1.069	0.931	1.021	0.110	2.055	3.106
22.	50000.	76.2	1.162	1.013	1.122	0.122	2.210	3.293
23.	65000.	75.6	1.287	1.126	1.268	0.137	2.411	3.525
24.	80000.	77.1	1.382	1.213	1.390	0.149	2.561	3.693
25.	100000.	77.4	1.485	1.313	1.541	0.168	2.725	3.876
26.	150000.	78.0	1.641	1.468	1.918	0.197	2.985	4.183
27.	200000.	78.0	1.726	1.557	2.444	0.208	3.137	4.357
28.	250000.	78.0	1.794	1.630	3.192	0.221	3.265	4.494
29.	300000.	78.8	1.849	1.697	10.096	0.230	3.369	4.614
29.	340000.	78.8	1.891	1.747	0.000	0.242	3.452	4.707
29.	340000.	76.5	1.888	1.747	0.000	0.237	3.444	4.672
30.	400000.	76.2	1.974	1.855	0.000	0.257	3.627	4.880
31.	500000.	76.3	2.083	2.013	0.000	0.277	3.838	5.121

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

* **Use second zero reading for initial zero (after 1 cycle)**

TABLE E-15 RESISTANCE CHANGE DATA FOR SPECIMEN #20

SPECIMEN NO. = 20

ALT STRAIN = 750 MEAN STRAIN = 500 ZERO TEMP = 73.8

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.663	-0.498	-0.514	-0.555	-0.546	-0.424

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	74.5	0.014	0.012	0.008	0.004	0.020	0.035
2.	25.	74.5	0.028	0.025	0.019	0.009	0.041	0.073
3.	50.	74.5	0.055	0.049	0.039	0.019	0.074	0.130
4.	100.	74.6	0.094	0.087	0.071	0.034	0.132	0.226
5.	150.	74.6	0.132	0.120	0.100	0.046	0.181	0.313
6.	200.	74.7	0.167	0.152	0.128	0.059	0.228	0.390
7.	300.	74.7	0.229	0.208	0.178	0.081	0.313	0.534
8.	500.	74.8	0.337	0.309	0.265	0.120	0.460	0.777
9.	700.	75.0	0.433	0.398	0.343	0.154	0.593	0.985
10.	1000.	74.8	0.565	0.523	0.451	0.205	0.767	1.258
11.	1500.	75.2	0.754	0.697	0.607	0.273	1.007	1.632
12.	2000.	75.6	0.925	0.855	0.747	0.339	1.224	1.949
13.	3000.	75.6	1.221	1.130	0.994	0.457	1.590	2.456
14.	5000.	76.1	1.676	1.555	1.381	0.661	2.120	3.135
15.	7000.	76.2	2.030	1.890	1.688	0.830	2.517	3.605
16.	10000.	76.2	2.406	2.251	2.023	1.022	2.926	4.052
17.	15000.	76.2	2.909	2.739	2.481	1.314	3.453	4.605
18.	20000.	76.2	3.249	3.076	2.799	1.537	3.798	4.950
19.	25000.	76.2	3.501	3.334	3.037	1.712	4.055	5.201
20.	30000.	77.0	3.688	3.537	3.218	1.852	4.247	5.412
21.	40000.	77.3	3.973	3.829	3.491	2.073	4.539	5.658
22.	50000.	77.7	4.185	4.050	3.691	2.244	4.757	5.861
23.	65000.	77.8	4.413	4.298	3.915	2.431	4.994	6.096
24.	80000.	78.2	4.590	4.511	4.082	2.571	5.172	6.270
24.	95000.	78.3	4.728	4.643	4.221	2.683	5.321	6.440
24.	95190.	73.4	4.686	4.675	4.184	2.659	5.303	6.422
25.	100000.	74.0	4.740	4.719	4.230	2.686	5.371	6.495
26.	150000.	76.8	5.101	5.033	4.549	2.910	5.739	6.947
27.	200000.	78.9	5.348	5.279	4.777	3.096	6.012	7.263
28.	250000.	79.4	5.543	5.483	4.954	3.255	6.233	7.584
29.	300000.	80.1	5.704	5.644	5.104	3.382	6.420	7.867
30.	400000.	80.0	6.026	6.002	5.402	3.628	6.820	8.598
31.	500000.	76.8	6.245	6.265	5.628	3.844	7.120	9.945
32.	750000.	80.3	7.064	7.346	6.404	4.556	8.398	0.000
33.	1000000.	77.4	7.753	8.351	7.070	5.418	10.261	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED
TO THE ZERO TEMPERATURE

TABLE E-16 RESISTANCE CHANGE DATA FOR SPECIMEN #21

SPECIMEN NO. = 21

ALT STRAIN = 1000 MEAN STRAIN = 500 ZERO TEMP = 75.9

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.106	-0.347	-0.435	-0.221	-0.203	-0.558

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.9	0.033	0.033	0.027	0.011	0.050	0.068
2.	25.	77.3	0.070	0.069	0.060	0.028	0.105	0.144
3.	50.	76.8	0.125	0.123	0.110	0.052	0.187	0.252
4.	100.	76.8	0.213	0.213	0.194	0.094	0.327	0.437
5.	150.	76.7	0.299	0.300	0.279	0.136	0.458	0.615
6.	200.	76.8	0.373	0.379	0.350	0.173	0.571	0.767
7.	300.	76.9	0.509	0.518	0.486	0.242	0.776	1.039
8.	500.	76.7	0.746	0.760	0.719	0.362	1.130	1.499
9.	700.	76.9	0.951	0.970	0.921	0.470	1.429	1.881
10.	1000.	76.7	1.207	1.244	1.182	0.609	1.804	2.347
11.	1500.	76.6	1.589	1.623	1.542	0.811	2.303	2.951
12.	2000.	76.7	1.902	1.943	1.846	0.994	2.706	3.409
13.	3000.	76.8	2.391	2.445	2.323	1.297	3.294	4.055
14.	5000.	77.0	3.023	3.131	2.970	1.760	4.030	4.840
15.	7000.	76.9	3.497	3.588	3.414	2.108	4.493	5.332
16.	10000.	77.0	3.945	4.054	3.866	2.489	4.958	5.910
17.	15000.	77.0	4.457	4.589	4.382	2.942	5.520	7.369
18.	20000.	77.0	4.777	4.924	4.703	3.255	5.888	8.194
19.	25000.	77.0	5.009	5.179	4.944	3.491	6.150	8.722
20.	30000.	77.7	5.190	5.383	5.139	3.679	6.377	9.662
21.	40000.	78.5	5.485	5.706	5.443	3.954	6.831	10.054
22.	50000.	78.5	5.709	5.960	5.706	4.166	7.556	0.000
23.	65000.	79.5	5.953	6.288	6.032	4.405	8.462	0.000
24.	80000.	79.2	6.180	6.580	6.590	4.599	0.000	0.000
24.	95000.	79.9	6.365	6.777	7.615	4.752	9.903	0.000
24.	95000.	75.3	6.291	6.679	7.573	4.716	8.973	0.000
25.	100000.	75.7	6.538	7.117	0.000	4.840	0.000	0.000
26.	150000.	78.9	7.222	7.892	0.000	5.333	0.000	0.000
27.	200000.	80.1	7.835	9.176	0.000	5.771	0.000	0.000
28.	250000.	80.2	8.658	0.000	0.000	6.246	0.000	0.000
29.	300000.	80.8	0.000	0.000	0.000	6.816	0.000	0.000
30.	400000.	76.7	0.000	0.000	0.000	0.000	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-17 RESISTANCE CHANGE DATA FOR SPECIMEN #22

SPECIMEN NO. = 22

ALT STRAIN = 1250 MEAN STRAIN = 500 ZERO TEMP = 77.2

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.530	-0.715	-0.306	-0.155	-0.497	-0.016

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.7	0.059	0.060	0.051	0.024	0.078	0.104
2.	25.	76.6	0.127	0.126	0.118	0.061	0.172	0.225
3.	50.	76.8	0.221	0.217	0.212	0.113	0.306	0.108
4.	100.	76.7	0.384	0.376	0.386	0.204	0.543	0.000
5.	150.	77.7	0.532	0.519	0.540	0.284	0.750	0.000
6.	200.	76.6	0.657	0.640	0.671	0.350	0.926	0.000
7.	300.	76.6	0.887	0.868	0.916	0.478	1.248	0.000
8.	500.	76.6	1.279	1.250	1.334	0.701	1.780	0.000
9.	700.	76.6	1.603	1.566	1.677	0.891	2.201	0.000
10.	1000.	76.7	2.003	1.965	2.103	1.138	2.704	0.000
11.	1500.	76.7	2.525	2.638	2.653	1.475	3.335	0.000
12.	2000.	76.7	2.945	0.000	3.089	1.757	3.804	0.000
13.	3000.	76.7	3.565	0.000	0.000	2.216	0.000	0.000
14.	5000.	76.7	4.345	0.000	0.000	2.854	0.000	0.000
15.	7000.	76.7	4.852	0.000	0.000	3.296	0.000	0.000
16.	10000.	77.2	5.368	0.000	0.000	3.769	0.000	0.000
17.	15000.	77.2	6.024	0.000	0.000	4.317	0.000	0.000
18.	20000.	77.2	6.533	0.000	0.000	4.706	0.000	0.000
19.	25000.	77.2	6.987	0.000	0.000	5.050	0.000	0.000
20.	30000.	78.8	7.502	0.000	0.000	5.329	0.000	0.000
21.	40000.	79.2	8.286	0.000	0.000	5.746	0.000	0.000
22.	50000.	80.0	9.069	0.000	0.000	6.033	0.000	0.000
22.	55000.	80.0	9.543	0.000	0.000	6.169	0.000	0.000
22.	55000.	73.6	9.791	0.000	0.000	6.158	0.000	0.000
23.	65000.	74.9	0.000	0.000	0.000	6.970	0.000	0.000
24.	80000.	75.1	0.000	0.000	0.000	7.820	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-18 RESISTANCE CHANGE DATA FOR SPECIMEN #23

SPECIMEN NO. = 23

ALT STRAIN = 1500 MEAN STRAIN = 500 ZERO TEMP = 73.0

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.325	-0.511	-0.314	-0.585	-0.331	-0.575

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	74.1	0.086	0.089	0.086	0.043	0.000	0.159
2.	25.	74.1	0.187	0.187	0.184	0.096	0.000	0.337
3.	50.	74.1	0.337	0.337	0.332	0.173	0.000	0.602
4.	100.	74.2	0.591	0.599	0.578	0.304	0.000	1.047
5.	150.	74.2	0.807	0.823	0.787	0.416	0.000	1.415
6.	200.	74.2	1.004	1.025	0.977	0.521	0.000	1.737
7.	300.	74.2	1.355	1.388	0.000	0.713	0.000	2.279
8.	500.	74.2	1.925	1.991	0.000	1.030	0.000	3.085
9.	700.	74.2	2.385	2.494	0.000	1.299	0.000	0.000
10.	1000.	75.0	2.924	3.111	0.000	1.639	0.000	0.000
11.	1500.	75.0	3.614	3.921	0.000	2.106	0.000	0.000
12.	2000.	75.0	4.119	4.557	0.000	2.474	0.000	0.000
13.	3000.	75.1	4.831	5.557	0.000	3.035	0.000	0.000
14.	5000.	75.1	5.732	7.223	0.000	3.753	0.000	0.000
15.	7000.	75.1	6.336	8.745	0.000	4.219	0.000	0.000
16.	10000.	76.3	7.109	0.000	0.000	4.699	0.000	0.000
17.	15000.	76.3	9.667	0.000	0.000	5.220	0.000	0.000
18.	20000.	78.6	0.000	0.000	0.000	5.576	0.000	0.000
19.	25000.	78.2	0.000	0.000	0.000	5.826	0.000	0.000
19.	25000.	76.2	0.000	0.000	0.000	5.778	0.000	0.000
20.	30000.	76.8	0.000	0.000	0.000	6.041	0.000	0.000
21.	40000.	78.0	0.000	0.000	0.000	6.340	0.000	0.000
22.	50000.	78.6	0.000	0.000	0.000	6.586	0.000	0.000
23.	65000.	78.5	0.000	0.000	0.000	6.872	0.000	0.000

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE E-19 ADJUSTED DELTA R MEAN STRAIN AT 10 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 10. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	*******	1000.	*******
2	6	4U	2039.	1007.	0.0012	1000.	0.0012
3	11	4U	-2055.	1036.	0.0185	1000.	0.0168
4	14	4U	-1012.	1012.	0.0062	1000.	0.0060
5	19	4U	998.	998.	0.0041	1000.	0.0041
6			0.	1200.	*******	1250.	*******
7	6	1U	2661.	1325.	0.0051	1250.	0.0044
8	6	2M	2641.	1303.	0.0041	1250.	0.0037
9	6	3L	2681.	1324.	0.0051	1250.	0.0044
10	11	1U	-2553.	1268.	0.0292	1250.	0.0281
11	11	2M	-2615.	1311.	0.0292	1250.	0.0258
12	11	3L	-2601.	1309.	0.0272	1250.	0.0242
13	14	1U	-1318.	1318.	0.0181	1250.	0.0158
14	14	2M	-1330.	1330.	0.0201	1250.	0.0171
15	14	3L	-1303.	1303.	0.0161	1250.	0.0145
16	19	1U	1324.	1324.	0.0060	1250.	0.0052
17	19	2M	1320.	1320.	0.0040	1250.	0.0035
18	19	3L	1317.	1317.	0.0050	1250.	0.0044
19			0.	1500.	0.0120	1500.	0.0120
20	6	5M	2941.	1459.	0.0082	1500.	0.0088
21	11	5M	-3019.	1527.	0.0384	1500.	0.0367
22	12	4U	-2094.	1578.	0.0213	1500.	0.0188
23	14	5M	-1538.	1538.	0.0262	1500.	0.0246
24	15	4U	-1026.	1549.	0.0189	1500.	0.0174
25	19	5M	1519.	1519.	0.0081	1500.	0.0078
26	20	4U	981.	1474.	0.0042	1500.	0.0044
27			0.	1700.	0.0160	1750.	0.0172
28	6	6L	3426.	1711.	0.0131	1750.	0.0138
29	11	6L	-3311.	1622.	0.0391	1750.	0.0470
30	14	6L	-1740.	1740.	0.0351	1750.	0.0356
31	19	6L	1727.	1727.	0.0120	1750.	0.0124
32			0.	2000.	0.0250	2000.	0.0250
33	8	4U	2112.	2112.	0.0122	2000.	0.0108
34	12	1U	-2684.	2018.	0.0431	2000.	0.0422
35	12	2M	-2705.	2036.	0.0381	2000.	0.0366
36	12	3L	-2640.	1989.	0.0401	2000.	0.0406
37	15	1U	-1287.	1936.	0.0260	2000.	0.0280
38	15	2M	-1275.	1924.	0.0280	2000.	0.0306

TABLE E-19 ADJUSTED DELTA R MEAN STRAIN AT 10 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 10. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	15	3L	-1278.	1934.	0.0320	2000.	0.0346
40	16	4U	-1030.	2093.	0.0341	2000.	0.0307
41	20	1U	1318.	1981.	0.0141	2000.	0.0144
42	20	2M	1297.	1940.	0.0121	2000.	0.0130
43	20	3L	1243.	1860.	0.0081	2000.	0.0096
44	21	4U	1007.	2004.	0.0114	2000.	0.0113
45			0.	2200.	0.0310	2250.	0.0326
46	12	5M	-3194.	2369.	0.0532	2250.	0.0474
47	15	5M	-1529.	2310.	0.0349	2250.	0.0329
48	20	5M	1462.	2192.	0.0202	2250.	0.0214
49			0.	2400.	0.0370	2500.	0.0405
50	8	1U	2708.	2708.	0.0261	2500.	0.0219
51	8	2M	2608.	2608.	0.0221	2500.	0.0201
52	8	3L	2602.	2602.	0.0281	2500.	0.0257
53	9	4U	2005.	2493.	0.0251	2500.	0.0253
54	12	6L	-3365.	2527.	0.0851	2500.	0.0831
55	15	6L	-1740.	2635.	0.0840	2500.	0.0749
56	16	1U	-1306.	2634.	0.0591	2500.	0.0527
57	16	2M	-1302.	2604.	0.0601	2500.	0.0550
58	16	3L	-1329.	2671.	0.0621	2500.	0.0538
59	17	4U	-1054.	2647.	0.0470	2500.	0.0415
60	20	6L	1717.	2558.	0.0351	2500.	0.0333
61	21	1U	1283.	2586.	0.0331	2500.	0.0308
62	21	2M	1307.	2611.	0.0331	2500.	0.0301
63	21	3L	1293.	2592.	0.0271	2500.	0.0251
64	22	4U	1013.	2553.	0.0248	2500.	0.0237
65			0.	3000.	0.0600	3000.	0.0600
66	8	5M	3057.	3057.	0.0372	3000.	0.0357
67	9	2M	2621.	3263.	0.0531	3000.	0.0446
68	9	3L	2631.	3283.	0.0481	3000.	0.0399
69	16	5M	-1507.	3020.	0.0681	3000.	0.0672
70	17	3L	-1249.	3258.	0.0770	3000.	0.0650
71	18	4U	-1031.	3085.	0.0700	3000.	0.0660
72	21	5M	1542.	3101.	0.0503	3000.	0.0469
73	22	1U	1298.	3286.	0.0599	3000.	0.0497
74	23	40	1015.	2992.	0.0434	3000.	0.0437
75			0.	3400.	0.0790	3500.	0.0837
76	8	6L	3559.	3559.	0.0661	3500.	0.0639
77	16	6L	-1667.	3487.	0.0961	3500.	0.0968

TABLE E-19 ADJUSTED DELTA R MEAN STRAIN AT 10 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 10. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
78	17	1U	-1294.	3379.	0.0830	3500.	0.0890
79	17	2M	-1292.	3325.	0.0740	3500.	0.0820
80	21	6L	1786.	3578.	0.0681	3500.	0.0652
81	22	2M	1294.	3300.	0.0609	3500.	0.0686
82	22	3L	1354.	3427.	0.0519	3500.	0.0542
83			0.	4000.	0.1130	4000.	0.1130
84	10	1U	2560.	3832.	0.0807	4000.	0.0877
85	10	2M	2573.	3873.	0.0937	4000.	0.0998
86	10	3L	2643.	3883.	0.0817	4000.	0.0865
87	17	5M	-1674.	4125.	0.1280	4000.	0.1207
88	18	1U	-1316.	4003.	0.1290	4000.	0.1288
89	18	2M	-1335.	3990.	0.1210	4000.	0.1216
90	18	3L	-1326.	3912.	0.1100	4000.	0.1148
91	22	5M	1519.	3849.	0.0789	4000.	0.0850
92	23	1U	1383.	4093.	0.0862	4000.	0.0825
93	23	2M	1383.	4063.	0.0892	4000.	0.0866
94			0.	4330.	0.1330	4500.	0.1447
95	9	6L	3487.	4328.	0.1041	4500.	0.1119
96	17	6L	-1777.	4544.	0.1650	4500.	0.1621
97	18	5M	-1643.	4839.	0.1710	4500.	0.1499
98			0.	5200.	0.2030	5200.	0.2030
99	18	6L	-1738.	5260.	0.2380	5200.	0.2333

TABLE E-20 ADJUSTED DELTA R MEAN STRAIN DATA AT 25 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 25. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	*******	1000.	*******
2	14	4U	-1012.	1012.	0.0082	1000.	0,0080
3	19	4U	998.	998.	0.0041	1000.	0.0041
4			0.	1200.	0.0110	1250.	0.0123
5	6	1U	2661.	1325.	0.0091	1250.	0.0077
6	6	2M	2641.	1303.	0.0081	1250.	0.0072
7	6	3L	2681.	1324.	0.0091	1250.	0.0078
8	14	1U	-1318.	1318.	0.0241	1250.	0.0208
9	14	2M	-1330.	1330.	0.0261	1250.	0.0220
10	14	3L	-1303.	1303.	0.0201	1250.	0.0179
11	19	1U	1324.	1324.	0.0090	1250.	0.0077
12	19	2M	1320.	1320.	0.0070	1250.	0.0061
13	19	3L	1317.	1317.	0.0090	1250.	0.0078
14			0.	1500.	0.0200	1500.	0.0200
15	6	5M	2941.	1459.	0.0152	1500.	0.0163
16	7	4U	2028.	1523.	0.0150	1500.	0.0144
17	12	4U	-2094.	1578.	0.0303	1500.	0.0265
18	14	5M	-1533.	1538.	0.0352	1500.	0.0329
19	15	4U	-1026.	1549.	0.0249	1500.	0.0229
20	19	5M	1519.	1519.	0.0141	1500.	0.0136
21	20	4U	981.	1474.	0.0092	1500.	0.0097
22			0.	1700.	0.0270	1750.	0.0291
23	6	6L	3426.	1711.	0.0281	1750.	0.0297
24	14	6L	-1740.	1740.	0.0491	1750.	0.0498
25	19	6L	1727.	1727.	0.0240	1750.	0.0249
26			0.	2000.	0.0410	2000.	0.0410
27	7	1U	2674.	2024.	0.0350	2000.	0.0340
28	7	2M	2573.	1944.	0.0360	2000.	0.0387
29	7	3L	2554.	1908.	0.0310	2000.	0.0349
30	8	4U	2112.	2112.	0.0332	2000.	0.0290
31	12	1U	-2684.	2018.	0.0631	2000.	0.0617
32	12	2M	-2705.	2036.	0.0571	2000.	0.0546
33	12	3L	-2640.	1989.	0.0591	2000.	0.0599
34	13	4U	-1990.	1990.	0.0578	2000.	0.0586
35	15	1U	-1287.	1936.	0.0380	2000.	0.0412
36	15	2M	-1275.	1924.	0.0420	2000.	0.0463
37	15	3L	-1278.	1934.	0.0480	2000.	0.0522
38	16	4U	-1030.	2093.	0.0572	2000.	0.0510

TABLE E-20 ADJUSTED DELTA R MEAN STRAIN DATA AT 25 CYCLES (CONT.)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 25. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	20	1U	1318.	1981.	0.0281	2000.	0.0288
40	20	2M	1297.	1940.	0.0251	2000.	0.0271
41	20	3L	1243.	1860.	0.0191	2000.	0.0230
42	21	4U	1007.	2004.	0.0285	2000.	0.0283
43			0.	2200.	0.0530	2250.	0.0560
44	7	5M	2958.	2223.	0.0490	2250.	0.0505
45	12	5M	-3194.	2369.	0.0782	2250.	0.0690
46	15	5M	-1529.	2310.	0.0609	2250.	0.0571
47	20	5M	1462.	2192.	0.0412	2250.	0.0439
48			0.	2400.	0.0650	2500.	0.0717
49	8	1U	2708.	2708.	0.0651	2500.	0.0538
50	8	2M	2608.	2608.	0.0571	2500.	0.0516
51	8	3L	2602.	2602.	0.0671	2500.	0.0610
52	9	4U	2005.	2493.	0.0631	2500.	0.0635
53	12	6L	-3365.	2527.	0.1241	2500.	0.1210
54	13	1U	-2666.	2666.	0.1240	2500.	0.1064
55	13	3L	-2584.	2584.	0.1210	2500.	0.1117
56	15	6L	-1740.	2635.	0.1170	2500.	0.1032
57	16	1U	-1306.	2634.	0.1021	2500.	0.0901
58	16	2M	-1302.	2604.	0.1001	2500.	0.0908
59	16	3L	-1329.	2671.	0.1081	2500.	0.0923
60	17	4U	-1054.	2647.	0.0830	2500.	0.0724
61	20	6L	1717.	2558.	0.0731	2500.	0.0692
62	21	1U	1283.	2586.	0.0702	2500.	0.0647
63	21	2M	1307.	2611.	0.0692	2500.	0.0624
64	21	3L	1293.	2592.	0.0602	2500.	0.0552
65	22	4U	1013.	2553.	0.0618	2500.	0.0588
66			0.	3000.	0.1100	3000.	0.1100
67	8	5M	3057.	3057.	0.0892	3000.	0.0854
68	9	2M	2621.	3263.	0.1191	3000.	0.0983
69	9	3L	2631.	3283.	0.1171	3000.	0.0953
70	13	5M	-3030.	3030.	0.1569	3000.	0.1534
71	16	5M	-1507.	3020.	0.1271	3000.	0.1252
72	17	3L	-1249.	3253.	0.1390	3000.	0.1152
73	18	4U	-1031.	3085.	0.1260	3000.	0.1182
74	21	5M	1542.	3101.	0.1054	3000.	0.0976
75	22	1U	1298.	3236.	0.1280	3000.	0.1040
76	23	4U	1015.	2992.	0.0964	3000.	0.0970
77			0.	3400.	0.1480	3500.	0.1579

TABLE E-20 ADJUSTED DELTA R MEAN STRAIN DATA AT 25 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 25. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
78	8	6L	3559.	3559.	0.1451	3500.	0.1398
79	13	6L	-3233.	3233.	0.2130	3500.	0.2544
80	16	6L	-1667.	3487.	0.1791	3500.	0.1805
81	17	1U	-1294.	3379.	0.1500	3500.	0.1622
82	17	2M	-1292.	3325.	0.1350	3500.	0.1514
83	21	6L	1786.	3578.	0.1441	3500.	0.1373
84	22	2M	1294.	3300.	0.1270	3500.	0.1448
85	22	3L	1354.	3427.	0.1189	3500.	0.1246
86			0.	4000.	0.2140	4000.	0.2140
87	10	1U	2560.	3832.	0.1748	4000.	0.1917
88	10	2M	2573.	3873.	0.1998	4000.	0.2142
89	10	3L	2643.	3883.	0.1818	4000.	0.1937
90	17	5M	-1674.	4125.	0.2280	4000.	0.2135
91	18	1U	-1316.	4003.	0.2391	4000.	0.2386
92	18	2M	-1335.	3990.	0.2170	4000.	0.2183
93	18	3L	-1326.	3912.	0.2020	4000.	0.2119
94	22	5M	1319.	3849.	0.1729	4000.	0.1878
95	23	1U	1383.	4093.	0.1872	4000.	0.1782
96	23	2M	1383.	4063.	0.1872	4000.	0.1811
97			0.	4300.	0.2520	4500.	0.2771
98	9	6L	3487.	4328.	0.2301	4500.	0.2496
99	17	6L	-1777.	4544.	0.2991	4500.	0.2931
100	18	5M	-1643.	4839.	0.3111	4500.	0.2680
101			0.	5200.	0.3830	5200.	0.3830
102	18	6L	-1738.	5260.	0.4101	5200.	0.4008

TABLE E-21 ADJUSTED DELTA R MEAN STRAIN DATA AT 50 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 50. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	*******	1000.	*******
2	6	4U	2039.	1007.	0.0032	1000.	0.0032
3	11	4U	-2055.	1036.	0.0255	1000.	0.0228
4	14	4U	-1012.	1012.	0.0102	1000.	0.0099
5	19	4U	993.	998.	0.0051	1000.	0.0051
6			0.	1200.	0.0140	1250.	0.0159
7	6	1U	2561.	1325.	0.0151	1250.	0.0126
8	6	2M	2641.	1303.	0.0151	1250.	0.0133
9	6	3L	2681.	1324.	0.0151	1250.	0.0127
10	11	1U	-2553.	1268.	0.0402	1250.	0.0385
11	11	2M	-2615.	1311.	0.0452	1250.	0.0391
12	11	3L	-2601.	1309.	0.0412	1250.	0.0358
13	14	1U	-1318.	1318.	0.0281	1250.	0.0239
14	14	2M	-1330.	1330.	0.0311	1250.	0.0257
15	14	3L	-1303.	1303.	0.0271	1250.	0.0239
16	19	1U	1324.	1324.	0.0140	1250.	0.0118
17	19	2M	1320.	1320.	0.0120	1250.	0.0102
18	19	3L	1317.	1317.	0.0140	1250.	0.0120
19			0.	1500.	0.0280	1500.	0.0280
20	6	5M	2941.	1459.	0.0232	1500.	0.0252
21	7	4U	2028.	1523.	0.0260	1500.	0.0249
22	11	5M	-3019.	1527.	0.0624	1500.	0.0592
23	12	4U	-2094.	1578.	0.0423	1500.	0.0365
24	14	5M	-1538.	1538.	0.0452	1500.	0.0420
25	15	4U	-1026.	1549.	0.0349	1500.	0.0318
26	19	5M	1519.	1519.	0.0251	1500.	0.0242
27	20	4U	981.	1474.	0.0192	1500.	0.0203
28			0.	1700.	0.0400	1750.	0.0435
29	6	6L	3426.	1711.	0.0451	1750.	0.0480
30	11	6L	-3311.	1622.	0.0621	1750.	0.0774
31	14	6L	-1740.	1740.	0.0651	1750.	0.0662
32	19	6L	1727.	1727.	0.0440	1750.	0.0458
33			0.	2000.	0.0630	2000.	0.0630
34	7	1U	2674.	2024.	0.0610	2000.	0.0590
35	7	2M	2573.	1944.	0.0620	2000.	0.0672
36	7	3L	2554.	1908.	0.0550	2000.	0.0628
37	8	4U	2112.	2112.	0.0643	2000.	0.0552
38	12	1U	-2684.	2018.	0.0881	2000.	0.0859

TABLE E-21 ADJUSTED DELTA R MEAN STRAIN DATA AT 50 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 50. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	0.0831	2000.	0.0791
40	12	3L	-2640.	1989.	0.0841	2000.	0.0854
41	13	4U	-1990.	1990.	0.0808	2000.	0.0820
42	15	1U	-1287.	1936.	0.0620	2000.	0.0679
43	15	2M	-1275.	1924.	0.0640	2000.	0.0714
44	15	3L	-1278.	1934.	0.0700	2000.	0.0769
45	16	4U	-1030.	2093.	0.0882	2000.	0.0777
46	20	1U	1318.	1981.	0.0551	2000.	0.0566
47	20	2M	1297.	1940.	0.0491	2000.	0.0535
48	20	3L	1243.	1860.	0.0391	2000.	0.0480
49	21	4U	1007.	2004.	0.0523	2000.	0.0520
50			0.	2200.	0.0820	2250.	0.0872
51	7	5M	2958.	2223.	0.0860	2250.	0.0890
52	12	5M	-3194.	2369.	0.1112	2250.	0.0967
53	15	5M	-1529.	2310.	0.0990	2250.	0.0921
54	20	5M	1462.	2192.	0.0742	2250.	0.0797
55			0.	2400.	0.1040	2500.	0.1161
56	8	1U	2708.	2708.	0.1201	2500.	0.0971
57	8	2M	2608.	2608.	0.1081	2500.	0.0966
58	8	3L	2602.	2602.	0.1231	2500.	0.1106
59	9	4U	2005.	2493.	0.1152	2500.	0.1160
60	12	6L	-3365.	2527.	0.1761	2500.	0.1712
61	13	1U	-2666.	2666.	0.1820	2500.	0.1533
62	13	3L	-2584.	2584.	0.1780	2500.	0.1629
63	15	6L	-1740.	2635.	0.1760	2500.	0.1529
64	16	1U	-1306.	2634.	0.1641	2500.	0.1427
65	16	2M	-1302.	2604.	0.1581	2500.	0.1418
66	16	3L	-1329.	2671.	0.1721	2500.	0.1442
67	17	4U	-1054.	2647.	0.1410	2500.	0.1211
68	20	6L	1717.	2558.	0.1301	2500.	0.1223
69	21	1U	1283.	2586.	0.1251	2500.	0.1143
70	21	2M	1307.	2611.	0.1231	2500.	0.1096
71	21	3L	1293.	2592.	0.1101	2500.	0.1000
72	22	4U	1013.	2553.	0.1139	2500.	0.1076
73			0.	3000.	0.1840	3000.	0.1840
74	8	5M	3057.	3057.	0.1632	3000.	0.1559
75	9	2M	2621.	3263.	0.2151	3000.	0.1761
76	9	3L	2631.	3283.	0.2111	3000.	0.1704
77	13	5M	-3030.	3030.	0.2319	3000.	0.2265
78	16	5M	-1507.	3020.	0.2141	3000.	0.2108

TABLE E-21 ADJUSTED DELTA R MEAN STRAIN DATA AT 50 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 50. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	17	3L	-1249.	3258.	0.2321	3000.	0.1906
80	18	4U	-1031.	3085.	0.2050	3000.	0.1916
81	21	5M	1542.	3101.	0.1873	3000.	0.1729
82	22	1U	1298.	3286.	0.2220	3000.	0.1788
83	23	4U	1015.	2992.	0.1734	3000.	0.1746
84			0.	3400.	0.2470	3500.	0.2638
85	8	6L	3559.	3559.	0.2581	3500.	0.2487
86	13	6L	-3233.	3233.	0.3140	3500.	0.3767
87	16	6L	-1667.	3487.	0.3001	3500.	0.3026
88	17	1U	-1294.	3379.	0.2511	3500.	0.2718
89	17	2M	-1292.	3325.	0.2311	3500.	0.2597
90	21	6L	1786.	3578.	0.2521	3500.	0.2400
91	22	2M	1294.	3300.	0.2180	3500.	0.2493
92	22	3L	1354.	3427.	0.2130	3500.	0.2233
93			0.	4000.	0.3550	4000.	0.3550
94	10	1U	2560.	3832.	0.3048	4000.	0.3338
95	10	2M	2573.	3873.	0.3438	4000.	0.3681
96	10	3L	2643.	3883.	0.3218	4000.	0.3425
97	17	5M	-1674.	4125.	0.3781	4000.	0.3547
98	18	1U	-1316.	4003.	0.3901	4000.	0.3894
99	18	2M	-1335.	3990.	0.3561	4000.	0.3580
100	18	3L	-1326.	3912.	0.3331	4000.	0.3489
101	22	5M	1519.	3849.	0.3070	4000.	0.3330
102	23	1U	1383.	4093.	0.3372	4000.	0.3215
103	23	2M	1383.	4063.	0.3372	4000.	0.3265
104			0.	4300.	0.4150	4500.	0.4540
105	9	6L	3487.	4328.	0.4111	4500.	0.4441
106	17	6L	-1777.	4544.	0.4981	4500.	0.4888
107	18	5M	-1643.	4839.	0.5181	4500.	0.4511
108			0.	5200.	0.6100	5200.	0.6100
109	18	6L	-1738.	5260.	0.6551	5200.	0.6419

TABLE E-22 ADJUSTED DELTA R MEAN STRAIN DATA AT 100 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 100. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	*******	1000.	*******
2	6	4U	2039.	1007.	0.0093	1000.	0.0090
3	11	4U	-2055.	1036.	0.0303	1000.	0.0265
4	14	4U	-1012.	1012.	0.0134	1000.	0.0128
5	19	4U	998.	998.	0.0063	1000.	0.0064
6			0.	1200.	0.0190	1250.	0.0220
7	6	1U	2661.	1325.	0.0281	1250.	0.0229
8	6	2M	2641.	1303.	0.0301	1250.	0.0260
9	6	3L	2681.	1324.	0.0291	1250.	0.0238
10	11	1U	-2553.	1268.	0.0471	1250.	0.0447
11	11	2M	-2615.	1311.	0.0561	1250.	0.0474
12	11	3L	-2601.	1309.	0.0531	1250.	0.0451
13	14	1U	-1318.	1318.	0.0362	1250.	0.0300
14	14	2M	-1330.	1330.	0.0412	1250.	0.0331
15	14	3L	-1303.	1303.	0.0362	1250.	0.0312
16	19	1U	1324.	1324.	0.0211	1250.	0.0172
17	19	2M	1320.	1320.	0.0181	1250.	0.0149
18	19	3L	1317.	1317.	0.0201	1250.	0.0167
19			0.	1500.	0.0420	1500.	0.0420
20	6	5M	2941.	1459.	0.0432	1500.	0.0476
21	7	4U	2028.	1523.	0.0456	1500.	0.0433
22	11	5M	-3019.	1527.	0.0782	1500.	0.0736
23	12	4U	-2094.	1578.	0.0592	1500.	0.0499
24	14	5M	-1538.	1538.	0.0603	1500.	0.0554
25	15	4U	-1026.	1549.	0.0499	1500.	0.0447
26	19	5M	1519.	1519.	0.0402	1500.	0.0386
27	20	4U	981.	1474.	0.0343	1500.	0.0364
28			0.	1700.	0.0630	1750.	0.0688
29	6	6L	3426.	1711.	0.0811	1750.	0.0868
30	11	6L	-3311.	1622.	0.0841	1750.	0.1066
31	14	6L	-1740.	1740.	0.0931	1750.	0.0948
32	19	6L	1727.	1727.	0.0731	1750.	0.0761
33			0.	2000.	0.1020	2000.	0.1020
34	7	1U	2674.	2024.	0.1073	2000.	0.1036
35	7	2M	2573.	1944.	0.1073	2000.	0.1169
36	7	3L	2554.	1908.	0.0993	2000.	0.1144
37	8	4U	2112.	2112.	0.1193	2000.	0.1016
38	12	1U	-2684.	2018.	0.1321	2000.	0.1286

TABLE E-22 ADJUSTED DELTA R MEAN STRAIN DATA AT 100 CYCLES (CONT.)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 100. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	0.1271	2000.	0.1206
40	12	3L	-2640.	1989.	0.1261	2000.	0.1281
41	13	4U	-1990.	1990.	0.1250	2000.	0.1269
42	15	1U	-1287.	1936.	0.0980	2000.	0.1080
43	15	2M	-1275.	1924.	0.1010	2000.	0.1135
44	15	3L	-1278.	1934.	0.1080	2000.	0.1194
45	16	4U	-1030.	2093.	0.1461	2000.	0.1278
46	20	1U	1318.	1981.	0.0941	2000.	0.0968
47	20	2M	1297.	1940.	0.0871	2000.	0.0954
48	20	3L	1243.	1860.	0.0711	2000.	0.0886
49	21	4U	1007.	2004.	0.0943	2000.	0.0937
50			0.	2200.	0.1350	2250.	0.1439
51	7	5M	2958.	2223.	0.1505	2250.	0.1558
52	12	5M	-3194.	2369.	0.1761	2250.	0.1524
53	15	5M	-1529.	2310.	0.1649	2250.	0.1531
54	20	5M	1462.	2192.	0.1322	2250.	0.1425
55			0.	2400.	0.1730	2500.	0.1934
56	8	1U	2708.	2708.	0.2222	2500.	0.1798
57	8	2M	2608.	2608.	0.2012	2500.	0.1796
58	8	3L	2602.	2602.	0.2232	2500.	0.2004
59	9	4U	2005.	2493.	0.2051	2500.	0.2066
60	12	6L	-3365.	2527.	0.2651	2500.	0.2577
61	13	1U	-2666.	2666.	0.2780	2500.	0.2344
62	13	3L	-2584.	2584.	0.2730	2500.	0.2498
63	15	6L	-1740.	2635.	0.2780	2500.	0.2416
64	16	1U	-1306.	2634.	0.2701	2500.	0.2350
65	16	2M	-1302.	2604.	0.2581	2500.	0.2315
66	16	3L	-1329.	2671.	0.2841	2500.	0.2382
67	17	4U	-1054.	2647.	0.2341	2500.	0.2010
68	20	6L	1717.	2558.	0.2261	2500.	0.2126
69	21	1U	1283.	2586.	0.2132	2500.	0.1947
70	21	2M	1307.	2611.	0.2132	2500.	0.1898
71	21	3L	1293.	2592.	0.1942	2500.	0.1762
72	22	4U	1013.	2553.	0.2049	2500.	0.1936
73			0.	3000.	0.3090	3000.	0.3090
74	8	5M	3057.	3057.	0.3003	3000.	0.2866
75	9	2M	2621.	3263.	0.3781	3000.	0.3086
76	9	3L	2631.	3283.	0.3751	3000.	0.3017
77	13	5M	-3030.	3030.	0.3620	3000.	0.3534
78	16	5M	-1507.	3020.	0.3552	3000.	0.3494

TABLE E-22 ADJUSTED DELTA R MEAN STRAIN DATA AT 100 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA AT 100. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	17	3L	-1249.	3258.	0.3851	3000.	0.3154
80	18	4U	-1031.	3085.	0.3421	3000.	0.3194
81	21	5M	1542.	3101.	0.3273	3000.	0.3017
82	22	1U	1298.	3286.	0.3850	3000.	0.3090
83	23	4U	1015.	2992.	0.3045	3000.	0.3066
84			0.	3400.	0.4170	3500.	0.4457
85	8	6L	3559.	3559.	0.4592	3500.	0.4422
86	13	6L	-3233.	3233.	0.4831	3500.	0.5810
87	16	6L	-1667.	3487.	0.5111	3500.	0.5154
88	17	1U	-1294.	3379.	0.4191	3500.	0.4543
89	17	2M	-1292.	3325.	0.3891	3500.	0.4380
90	21	6L	1786.	3578.	0.4372	3500.	0.4159
91	22	2M	1294.	3300.	0.3770	3500.	0.4320
92	22	3L	1354.	3427.	0.3870	3500.	0.4061
93			0.	4000.	0.6010	4000.	0.6010
94	10	1U	2560.	3832.	0.5238	4000.	0.5741
95	10	2M	2573.	3873.	0.5898	4000.	0.6319
96	10	3L	2643.	3883.	0.5638	4000.	0.6004
97	17	5M	-1674.	4125.	0.6271	4000.	0.5831
98	18	1U	-1316.	4003.	0.6452	4000.	0.6441
99	18	2M	-1335.	3990.	0.5931	4000.	0.5964
100	18	3L	-1326.	3912.	0.5611	4000.	0.5882
101	22	5M	1519.	3849.	0.5440	4000.	0.5905
102	23	1U	1383.	4093.	0.5913	4000.	0.5635
103	23	2M	1383.	4063.	0.5993	4000.	0.5800
104			0.	4300.	0.6990	4500.	0.7651
105	9	6L	3487.	4328.	0.7202	4500.	0.7782
106	17	6L	-1777.	4544.	0.8232	4500.	0.8078
107	18	5M	-1643.	4839.	0.8662	4500.	0.7540
108			0.	5200.	1.0080	5200.	1.0080
109	18	6L	-1738.	5260.	1.0612	5200.	1.0400

TABLE E-23 ADJUSTED DELTA R MEAN STRAIN DATA AT 150 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA AT 150. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	*******	1000.	*******
2	6	4U	2039.	1007.	0.0115	1000.	0.0112
3	11	4U	-2055.	1036.	0.0323	1000.	0.0277
4	14	4U	-1012.	1012.	0.0124	1000.	0.0118
5	19	4U	998.	998.	0.0061	1000.	0.0062
6			0.	1200.	0.0220	1250.	0.0259
7	6	1U	2661.	1325.	0.0382	1250.	0.0304
8	6	2M	2641.	1303.	0.0402	1250.	0.0342
9	6	3L	2681.	1324.	0.0382	1250.	0.0305
10	11	1U	-2553.	1268.	0.0531	1250.	0.0501
11	11	2M	-2615.	1311.	0.0671	1250.	0.0557
12	11	3L	-2601.	1309.	0.0611	1250.	0.0510
13	14	1U	-1318.	1318.	0.0422	1250.	0.0343
14	14	2M	-1330.	1330.	0.0472	1250.	0.0370
15	14	3L	-1303.	1303.	0.0412	1250.	0.0350
16	19	1U	1324.	1324.	0.0260	1250.	0.0208
17	19	2M	1320.	1320.	0.0220	1250.	0.0178
18	19	3L	1317.	1317.	0.0250	1250.	0.0204
19			0.	1500.	0.0520	1500.	0.0520
20	6	5M	2941.	1459.	0.0544	1500.	0.0602
21	7	4U	2028.	1523.	0.0676	1500.	0.0640
22	11	5M	-3019.	1527.	0.0942	1500.	0.0884
23	12	4U	-2094.	1578.	0.0780	1500.	0.0650
24	14	5M	-1538.	1538.	0.0733	1500.	0.0670
25	15	4U	-1026.	1549.	0.0659	1500.	0.0586
26	19	5M	1519.	1519.	0.0531	1500.	0.0508
27	20	4U	981.	1474.	0.0463	1500.	0.0493
28			0.	1700.	0.0810	1750.	0.0894
29	6	6L	3426.	1711.	0.1111	1750.	0.1199
30	11	6L	-3311.	1622.	0.1001	1750.	0.1301
31	14	6L	-1740.	1740.	0.1171	1750.	0.1195
32	19	6L	1727.	1727.	0.0960	1750.	0.1006
33			0.	2000.	0.1380	2000.	0.1380
34	7	1U	2674.	2024.	0.1553	2000.	0.1496
35	7	2M	2573.	1944.	0.1533	2000.	0.1678
36	7	3L	2554.	1908.	0.1423	2000.	0.1654
37	8	4U	2112.	2112.	0.1625	2000.	0.1372
38	12	1U	-2684.	2018.	0.1740	2000.	0.1691

TABLE E-23 ADJUSTED DELTA R MEAN STRAIN DATA AT 150 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 150. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	0.1670	2000.	0.1580
40	12	3L	-2640.	1939.	0.1670	2000.	0.1699
41	13	4U	-1990.	1990.	0.1629	2000.	0.1657
42	15	1U	-1287.	1936.	0.1320	2000.	0.1464
43	15	2M	-1275.	1924.	0.1350	2000.	0.1528
44	15	3L	-1278.	1934.	0.1440	2000.	0.1601
45	16	4U	-1030.	2093.	0.1921	2000.	0.1668
46	20	1U	1318.	1981.	0.1321	2000.	0.1361
47	20	2M	1297.	1940.	0.1201	2000.	0.1323
48	20	3L	1243.	1860.	0.1001	2000.	0.1265
49	21	4U	1007.	2004.	0.1363	2000.	0.1354
50			0.	2200.	0.1850	2250.	0.1978
51	7	5M	2958.	2223.	0.2155	2250.	0.2235
52	12	5M	-3194.	2369.	0.2331	2250.	0.2007
53	15	5M	-1529.	2310.	0.2240	2250.	0.2073
54	20	5M	1462.	2192.	0.1812	2250.	0.1959
55			0.	2400.	0.2380	2500.	0.2668
56	8	1U	2708.	2708.	0.3043	2500.	0.2454
57	8	2M	2608.	2608.	0.2742	2500.	0.2444
58	8	3L	2602.	2602.	0.3023	2500.	0.2709
59	9	4U	2005.	2493.	0.2851	2500.	0.2873
60	12	6L	-3365.	2527.	0.3491	2500.	0.3391
61	13	1U	-2666.	2666.	0.3640	2500.	0.3060
62	13	3L	-2584.	2584.	0.3570	2500.	0.3261
63	15	6L	-1740.	2635.	0.3691	2500.	0.3199
64	16	1U	-1306.	2634.	0.3571	2500.	0.3098
65	16	2M	-1302.	2604.	0.3391	2500.	0.3036
66	16	3L	-1329.	2671.	0.3701	2500.	0.3094
67	17	4U	-1054.	2647.	0.3182	2500.	0.2725
68	20	6L	1717.	2558.	0.3131	2500.	0.2940
69	21	1U	1283.	2586.	0.2992	2500.	0.2727
70	21	2M	1307.	2611.	0.3002	2500.	0.2666
71	21	3L	1293.	2592.	0.2792	2500.	0.2529
72	22	4U	1013.	2553.	0.2842	2500.	0.2683
73			0.	3000.	0.4290	3000.	0.4290
74	8	5M	3057.	3057.	0.4084	3000.	0.3900
75	9	2M	2621.	3263.	0.5211	3000.	0.4269
76	9	3L	2631.	3283.	0.5201	3000.	0.4200
77	13	5M	-3030.	3030.	0.4770	3000.	0.4658
78	16	5M	-1507.	3020.	0.4732	3000.	0.4656

TABLE E-23 ADJUSTED DELTA R MEAN STRAIN DATA AT 150 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 150. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	17	3L	-1249.	3258.	0.5212	3000.	0.4284
80	18	4U	-1031.	3085.	0.4611	3000.	0.4309
81	21	5M	1542.	3101.	0.4583	3000.	0.4229
82	22	1U	1298.	3286.	0.5322	3000.	0.4289
83	23	4U	1015.	2992.	0.4165	3000.	0.4194
84			0.	3400.	0.5750	3500.	0.6129
85	8	6L	3559.	3559.	0.6222	3500.	0.6002
86	13	6L	-3233.	3233.	0.6301	3500.	0.7531
87	16	6L	-1667.	3487.	0.6802	3500.	0.6856
88	17	1U	-1294.	3379.	0.5672	3500.	0.6129
89	17	2M	-1292.	3325.	0.5282	3500.	0.5920
90	21	6L	1786.	3578.	0.6152	3500.	0.5867
91	22	2M	1294.	3300.	0.5192	3500.	0.5920
92	22	3L	1354.	3427.	0.5402	3500.	0.5657
93			0.	4000.	0.8080	4000.	0.8080
94	10	1U	2560.	3832.	0.7208	4000.	0.7923
95	10	2M	2573.	3873.	0.8119	4000.	0.8716
96	10	3L	2643.	3883.	0.7819	4000.	0.8342
97	17	5M	-1674.	4125.	0.8473	4000.	0.7930
98	18	1U	-1316.	4003.	0.8682	4000.	0.8667
99	18	2M	-1335.	3990.	0.7972	4000.	0.8017
100	18	3L	-1326.	3912.	0.7552	4000.	0.7926
101	22	5M	1519.	3849.	0.7503	4000.	0.8164
102	23	1U	1383.	4093.	0.8073	4000.	0.7683
103	23	2M	1383.	4063.	0.8233	4000.	0.7962
104			0.	4300.	0.9370	4500.	1.0280
105	9	6L	3487.	4328.	0.9862	4500.	1.0679
106	17	6L	-1777.	4544.	1.1023	4500.	1.0811
107	18	5M	-1643.	4839.	1.1673	4500.	1.0126
108			0.	5200.	1.3430	5200.	1.3430
109	18	6L	-1738.	5260.	1.4073	5200.	1.3785

TABLE E-24 ADJUSTED DELTA R MEAN STRAIN DATA AT 200 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 200. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0110	1000.	0.0110
2	6	4U	2039.	1007.	0.0155	1000.	0.0150
3	11	4U	-2055.	1036.	0.0363	1000.	0.0309
4	14	4U	-1012.	1012.	0.0124	1000.	0.0118
5	19	4U	998.	998.	0.0071	1000.	0.0072
6			0.	1200.	0.0260	1250.	0.0309
7	6	1U	2661.	1325.	0.0472	1250.	0.0372
8	6	2M	2641.	1303.	0.0492	1250.	0.0415
9	6	3L	2681.	1324.	0.0482	1250.	0.0381
10	11	1U	-2553.	1268.	0.0611	1250.	0.0576
11	11	2M	-2615.	1311.	0.0761	1250.	0.0626
12	11	3L	-2601.	1309.	0.0701	1250.	0.0581
13	14	1U	-1318.	1318.	0.0452	1250.	0.0364
14	14	2M	-1330.	1330.	0.0512	1250.	0.0397
15	14	3L	-1303.	1303.	0.0452	1250.	0.0381
16	19	1U	1324.	1324.	0.0320	1250.	0.0254
17	19	2M	1320.	1320.	0.0280	1250.	0.0224
18	19	3L	1317.	1317.	0.0310	1250.	0.0250
19			0.	1500.	0.0630	1500.	0.0630
20	6	5M	2941.	1459.	0.0684	1500.	0.0760
21	7	4U	2028.	1523.	0.0826	1500.	0.0780
22	11	5M	-3019.	1527.	0.1092	1500.	0.1022
23	12	4U	-2094.	1578.	0.0920	1500.	0.0761
24	14	5M	-1538.	1538.	0.0833	1500.	0.0759
25	15	4U	-1026.	1549.	0.0769	1500.	0.0681
26	19	5M	1519.	1519.	0.0661	1500.	0.0631
27	20	4U	981.	1474.	0.0593	1500.	0.0634
28			0.	1700.	0.1020	1750.	0.1122
29	6	6L	3426.	1711.	0.1371	1750.	0.1476
30	11	6L	-3311.	1622.	0.1211	1750.	0.1558
31	14	6L	-1740.	1740.	0.1361	1750.	0.1388
32	19	6L	1727.	1727.	0.1200	1750.	0.1255
33			0.	2000.	0.1700	2000.	0.1700
34	7	1U	2674.	2024.	0.1883	2000.	0.1816
35	7	2M	2573.	1944.	0.1873	2000.	0.2045
36	7	3L	2554.	1908.	0.1733	2000.	0.2005
37	8	4U	2112.	2112.	0.2015	2000.	0.1709
38	12	1U	-2684.	2018.	0.2110	2000.	0.2053

TABLE E-24 ADJUSTED DELTA R MEAN STRAIN DATA AT 200 CYCLES (CONT.)

ADJUSTED DELTA R MEAN STRAIN DATA AT 200. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	0.2020	2000.	0.1914
40	12	3L	-2640.	1989.	0.2010	2000.	0.2044
41	13	4U	-1990.	1990.	0.1969	2000.	0.2001
42	15	1U	-1287.	1936.	0.1610	2000.	0.1780
43	15	2M	-1275.	1924.	0.1630	2000.	0.1838
44	15	3L	-1278.	1934.	0.1740	2000.	0.1929
45	20	1U	1318.	1981.	0.1672	2000.	0.1720
46	20	2M	1297.	1940.	0.1522	2000.	0.1671
47	20	3L	1243.	1860.	0.1281	2000.	0.1607
48	21	4U	1007.	2004.	0.1734	2000.	0.1722
49			0.	2200.	0.2270	2250.	0.2423
50	7	5M	2958.	2223.	0.2605	2250.	0.2699
51	12	5M	-3194.	2369.	0.2841	2250.	0.2452
52	15	5M	-1529.	2310.	0.2760	2250.	0.2559
53	20	5M	1462.	2192.	0.2283	2250.	0.2463
54			0.	2400.	0.2910	2500.	0.3258
55	8	1U	2708.	2708.	0.3773	2500.	0.3048
56	8	2M	2608.	2608.	0.3413	2500.	0.3044
57	8	3L	2602.	2602.	0.3753	2500.	0.3367
58	9	4U	2005.	2493.	0.3551	2500.	0.3578
59	12	6L	-3365.	2527.	0.4201	2500.	0.4082
60	13	1U	-2666.	2666.	0.4401	2500.	0.3704
61	13	3L	-2584.	2584.	0.4311	2500.	0.3940
62	15	6L	-1740.	2635.	0.4471	2500.	0.3880
63	17	4U	-1054.	2647.	0.3942	2500.	0.3381
64	20	6L	1717.	2558.	0.3902	2500.	0.3665
65	21	1U	1283.	2586.	0.3732	2500.	0.3405
66	21	2M	1307.	2611.	0.3792	2500.	0.3372
67	21	3L	1293.	2592.	0.3502	2500.	0.3175
68	22	4U	1013.	2553.	0.3509	2500.	0.3314
69			0.	3000.	0.5220	3000.	0.5220
70	8	5M	3057.	3057.	0.5065	3000.	0.4835
71	9	2M	2621.	3263.	0.6482	3000.	0.5297
72	9	3L	2631.	3283.	0.6462	3000.	0.5204
73	13	5M	-3030.	3030.	0.5771	3000.	0.5633
74	17	3L	-1249.	3258.	0.6452	3000.	0.5290
75	18	4U	-1031.	3085.	0.5702	3000.	0.5325
76	21	5M	1542.	3101.	0.5713	3000.	0.5269
77	22	1U	1298.	3236.	0.6581	3000.	0.5290
78	23	4U	1015.	2992.	0.5215	3000.	0.5252
79			0.	3400.	0.6940	3500.	0.7410

TABLE E-24 ADJUSTED DELTA R MEAN STRAIN DATA AT 200 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 200. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
80	8	6L	3559.	3559.	0.7683	3500.	0.7403
81	13	6L	-3233.	3233.	0.7612	3500.	0.9131
82	17	1U	-1294.	3379.	0.6972	3500.	0.7548
83	17	2M	-1292.	3325.	0.6512	3500.	0.7318
84	21	6L	1786.	3578.	0.7672	3500.	0.7307
85	22	2M	1294.	3300.	0.6411	3500.	0.7331
86	22	3L	1354.	3427.	0.6721	3500.	0.7046
87			0.	4000.	0.9990	4000.	0.9990
88	10	1U	2560.	3832.	0.8869	4000.	0.9713
89	10	2M	2573.	3873.	1.0019	4000.	1.0729
90	10	3L	2643.	3883.	0.9669	4000.	1.0292
91	17	5M	-1674.	4125.	1.0433	4000.	0.9782
92	18	1U	-1316.	4003.	1.0693	4000.	1.0675
93	18	2M	-1335.	3990.	0.9822	4000.	0.9876
94	18	3L	-1326.	3912.	0.9312	4000.	0.9758
95	22	5M	1519.	3849.	0.9271	4000.	1.0056
96	23	1U	1383.	4093.	1.0044	4000.	0.9571
97	23	2M	1383.	4063.	1.0254	4000.	0.9925
98			0.	4300.	1.1450	4500.	1.2563
99	9	6L	3487.	4328.	1.2153	4500.	1.3160
100	17	6L	-1777.	4544.	1.3453	4500.	1.3192
101	18	5M	-1643.	4839.	1.4304	4500.	1.2371
102			0.	5200.	1.6710	5200.	1.6710
103	18	6L	-1738.	5260.	1.7104	5200.	1.6730

TABLE E-25 ADJUSTED DELTA R MEAN STRAIN DATA AT 300 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 300. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0130	1000.	0.0130
2	6	4U	2039.	1007.	0.0185	1000.	0.0178
3	11	4U	-2055.	1036.	0.0403	1000.	0.0334
4	14	4U	-1012.	1012.	0.0164	1000.	0.0154
5	19	4U	998.	998.	0.0091	1000.	0.0092
6			0.	1200.	0.0320	1250.	0.0388
7	6	1U	2661.	1325.	0.0612	1250.	0.0470
8	6	2M	2641.	1303.	0.0642	1250.	0.0531
9	6	3L	2681.	1324.	0.0612	1250.	0.0472
10	11	1U	-2553.	1268.	0.0721	1250.	0.0674
11	11	2M	-2615.	1311.	0.0911	1250.	0.0733
12	11	3L	-2601.	1309.	0.0831	1250.	0.0674
13	14	1U	-1318.	1318.	0.0572	1250.	0.0450
14	14	2M	-1330.	1330.	0.0652	1250.	0.0492
15	14	3L	-1303.	1303.	0.0572	1250.	0.0473
16	19	1U	1324.	1324.	0.0440	1250.	0.0340
17	19	2M	1320.	1320.	0.0380	1250.	0.0297
18	19	3L	1317.	1317.	0.0410	1250.	0.0323
19			0.	1500.	0.0820	1500.	0.0820
20	6	5M	2941.	1459.	0.0874	1500.	0.0979
21	11	5M	-3019.	1527.	0.1312	1500.	0.1222
22	12	4U	-2094.	1578.	0.1190	1500.	0.0973
23	14	5M	-1538.	1538.	0.1053	1500.	0.0953
24	15	4U	-1026.	1549.	0.1019	1500.	0.0896
25	19	5M	1519.	1519.	0.0901	1500.	0.0857
26	20	4U	981.	1474.	0.0813	1500.	0.0873
27			0.	1700.	0.1350	1750.	0.1499
28	6	6L	3426.	1711.	0.1801	1750.	0.1953
29	11	6L	-3311.	1622.	0.1551	1750.	0.2055
30	14	6L	-1740.	1740.	0.1771	1750.	0.1809
31	19	6L	1727.	1727.	0.1641	1750.	0.1722
32			0.	2000.	0.2350	2000.	0.2350
33	8	4U	2112.	2112.	0.2756	2000.	0.2331
34	12	1U	-2684.	2018.	0.2771	2000.	0.2693
35	12	2M	-2705.	2036.	0.2681	2000.	0.2536
36	12	3L	-2640.	1989.	0.2641	2000.	0.2686
37	13	4U	-1990.	1990.	0.2610	2000.	0.2653
38	15	1U	-1287.	1936.	0.2160	2000.	0.2397

TABLE E-25 ADJUSTED DELTA R MEAN STRAIN DATA AT 300 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA AT 300. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	15	2M	-1275.	1924.	0.2190	2000.	0.2482
40	15	3L	-1278.	1934.	0.2320	2000.	0.2582
41	16	4U	-1030.	2093.	0.2992	2000.	0.2602
42	20	1U	1318.	1981.	0.2292	2000.	0.2361
43	20	2M	1297.	1940.	0.2082	2000.	0.2294
44	20	3L	1243.	1860.	0.1782	2000.	0.2258
45	21	4U	1007.	2004.	0.2424	2000.	0.2407
46			0.	2200.	0.3020	2250.	0.3217
47	12	5M	-3194.	2369.	0.3791	2250.	0.3300
48	15	5M	-1529.	2310.	0.3730	2250.	0.3471
49	20	5M	1462.	2192.	0.3133	2250.	0.3372
50			0.	2400.	0.4010	2500.	0.4507
51	8	1U	2708.	2708.	0.5123	2500.	0.4120
52	8	2M	2608.	2608.	0.4693	2500.	0.4174
53	8	3L	2602.	2602.	0.5133	2500.	0.4592
54	9	4U	2005.	2493.	0.4831	2500.	0.4869
55	12	6L	-3365.	2527.	0.5521	2500.	0.5360
56	13	1U	-2666.	2666.	0.5791	2500.	0.4855
57	13	3L	-2534.	2584.	0.5641	2500.	0.5144
58	15	6L	-1740.	2635.	0.5921	2500.	0.5121
59	16	1U	-1306.	2634.	0.5622	2500.	0.4867
60	16	2M	-1302.	2604.	0.5342	2500.	0.4773
61	16	3L	-1329.	2671.	0.5832	2500.	0.4863
62	17	4U	-1054.	2647.	0.5263	2500.	0.4497
63	20	6L	1717.	2558.	0.5342	2500.	0.5010
64	21	1U	1283.	2586.	0.5092	2500.	0.4635
65	21	2M	1307.	2611.	0.5182	2500.	0.4595
66	21	3L	1293.	2592.	0.4862	2500.	0.4397
67	22	4U	1013.	2553.	0.4789	2500.	0.4515
68			0.	3000.	0.7270	3000.	0.7270
69	8	5M	3057.	3057.	0.6835	3000.	0.6532
70	9	2M	2621.	3263.	0.8782	3000.	0.7228
71	9	3L	2631.	3283.	0.8762	3000.	0.7112
72	13	5M	-3030.	3030.	0.7581	3000.	0.7405
73	16	5M	-1507.	3020.	0.7432	3000.	0.7316
74	17	3L	-1249.	3258.	0.8602	3000.	0.7103
75	18	4U	-1031.	3085.	0.7622	3000.	0.7131
76	21	5M	1542.	3101.	0.7764	3000.	0.7175
77	22	1U	1298.	3286.	0.8881	3000.	0.7195
78	23	4U	1015.	2992.	0.7136	3000.	0.7185
79			0.	3400.	0.9660	3500.	1.0267

TABLE E-25 ADJUSTED DELTA R MEAN STRAIN DATA AT 300 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA AT 300. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
80	8	6L	3559.	3559.	1.0263	3500.	0.9918
81	13	6L	-3233.	3233.	0.9922	3500.	1.1774
82	16	6L	-1667.	3487.	1.0723	3500.	1.0804
83	17	1U	-1294.	3379.	0.9273	3500.	0.9984
84	17	2M	-1292.	3325.	0.8673	3500.	0.9672
85	21	6L	1786.	3578.	1.0393	3500.	0.9936
86	22	2M	1294.	3300.	0.8691	3500.	0.9855
87	22	3L	1354.	3427.	0.9171	3500.	0.9583
88			0.	4000.	1.3310	4000.	1.3310
89	10	1U	2560.	3832.	1.1829	4000.	1.2919
90	10	2M	2573.	3873.	1.3320	4000.	1.4230
91	10	3L	2643.	3883.	1.2919	4000.	1.3724
92	17	5M	-1674.	4125.	1.3844	4000.	1.3018
93	18	1U	-1316.	4003.	1.4234	4000.	1.4211
94	18	2M	-1335.	3990.	1.3043	4000.	1.3111
95	18	3L	-1326.	3912.	1.2403	4000.	1.2976
96	22	5M	1519.	3849.	1.2491	4000.	1.3514
97	23	1U	1333.	4093.	1.3555	4000.	1.2944
98	23	2M	1333.	4063.	1.3885	4000.	1.3458
99			0.	4300.	1.5340	4500.	1.6709
100	9	6L	3487.	4328.	1.6154	4500.	1.7383
101	17	6L	-1777.	4544.	1.7544	4500.	1.7234
102	18	5M	-1643.	4839.	1.8805	4500.	1.6508
103			0.	5200.	2.1500	5200.	2.1500
104	18	6L	-1738.	5260.	2.2175	5200.	2.1765

TABLE E-26 ADJUSTED DELTA R MEAN STRAIN DATA AT 500 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA AT 500. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0160	1000.	0.0160
2	6	4U	2039.	1007.	0.0246	1000.	0.0237
3	11	4U	-2055.	1036.	0.0453	1000.	0.0373
4	14	4U	-1012.	1012.	0.0194	1000.	0.0182
5	19	4U	998.	998.	0.0121	1000.	0.0122
6			0.	1200.	0.0420	1250.	0.0513
7	6	1U	2661.	1325.	0.0833	1250.	0.0632
8	6	2M	2641.	1303.	0.0883	1250.	0.0724
9	6	3L	2681.	1324.	0.0843	1250.	0.0642
10	11	1U	-2553.	1268.	0.0891	1250.	0.0831
11	11	2M	-2615.	1311.	0.1141	1250.	0.0910
12	11	3L	-2601.	1309.	0.1031	1250.	0.0829
13	14	1U	-1318.	1318.	0.0722	1250.	0.0562
14	14	2M	-1330.	1330.	0.0832	1250.	0.0621
15	14	3L	-1303.	1303.	0.0752	1250.	0.0618
16	19	1U	1324.	1324.	0.0621	1250.	0.0473
17	19	2M	1320.	1320.	0.0561	1250.	0.0433
18	19	3L	1317.	1317.	0.0611	1250.	0.0476
19			0.	1500.	0.1180	1500.	0.1180
20	6	5M	2941.	1459.	0.1195	1500.	0.1343
21	7	4U	2028.	1523.	0.1707	1500.	0.1601
22	11	5M	-3019.	1527.	0.1682	1500.	0.1563
23	12	4U	-2094.	1578.	0.1613	1500.	0.1310
24	14	5M	-1538.	1538.	0.1413	1500.	0.1275
25	15	4U	-1026.	1549.	0.1429	1500.	0.1251
26	19	5M	1519.	1519.	0.1311	1500.	0.1246
27	20	4U	981.	1474.	0.1204	1500.	0.1296
28			0.	1700.	0.1940	1750.	0.2160
29	6	6L	3426.	1711.	0.2532	1750.	0.2750
30	11	6L	-3311.	1622.	0.2101	1750.	0.2803
31	14	6L	-1740.	1740.	0.2451	1750.	0.2506
32	19	6L	1727.	1727.	0.2421	1750.	0.2544
33			0.	2000.	0.3420	2000.	0.3420
34	7	1U	2674.	2024.	0.3763	2000.	0.3626
35	7	2M	2573.	1944.	0.3733	2000.	0.4094
36	7	3L	2554.	1908.	0.3503	2000.	0.4086
37	8	4U	2112.	2112.	0.4167	2000.	0.3520
38	12	1U	-2684.	2018.	0.3862	2000.	0.3752

TABLE E-26 ADJUSTED DELTA R MEAN STRAIN DATA AT 500 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA AT 500. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	0.3772	2000.	0.3567
40	12	3L	-2640.	1989.	0.3692	2000.	0.3756
41	13	4U	-1990.	1990.	0.3700	2000.	0.3762
42	15	1U	-1287.	1936.	0.3140	2000.	0.3489
43	15	2M	-1275.	1924.	0.3140	2000.	0.3564
44	15	3L	-1278.	1934.	0.3280	2000.	0.3655
45	16	4U	-1030.	2093.	0.4242	2000.	0.3685
46	20	1U	1318.	1981.	0.3372	2000.	0.3475
47	20	2M	1297.	1940.	0.3092	2000.	0.3411
48	20	3L	1243.	1860.	0.2652	2000.	0.3372
49	21	4U	1007.	2004.	0.3624	2000.	0.3598
50			0.	2200.	0.4560	2250.	0.4857
51	7	5M	2958.	2223.	0.5065	2250.	0.5242
52	12	5M	-3194.	2369.	0.5533	2250.	0.4820
53	15	5M	-1529.	2310.	0.5410	2250.	0.5036
54	20	5M	1462.	2192.	0.4603	2250.	0.4955
55			0.	2400.	0.5760	2500.	0.6444
56	8	1U	2708.	2708.	0.7654	2500.	0.6200
57	8	2M	2608.	2608.	0.7044	2500.	0.6290
58	8	3L	2602.	2602.	0.7634	2500.	0.6856
59	9	4U	2005.	2493.	0.7075	2500.	0.7128
60	12	6L	-3365.	2527.	0.7702	2500.	0.7486
61	13	1U	-2666.	2666.	0.8171	2500.	0.6892
62	13	3L	-2584.	2584.	0.7971	2500.	0.7293
63	15	6L	-1740.	2635.	0.8432	2500.	0.7329
64	16	1U	-1306.	2634.	0.7922	2500.	0.6893
65	16	2M	-1302.	2604.	0.7502	2500.	0.6731
66	16	3L	-1329.	2671.	0.8262	2500.	0.6932
67	17	4U	-1054.	2647.	0.7603	2500.	0.6532
68	20	6L	1717.	2558.	0.7772	2500.	0.7306
69	21	1U	1283.	2586.	0.7463	2500.	0.6815
70	21	2M	1307.	2611.	0.7603	2500.	0.6769
71	21	3L	1293.	2592.	0.7193	2500.	0.6528
72	22	4U	1013.	2553.	0.7020	2500.	0.6633
73			0.	3000.	1.0190	3000.	1.0190
74	8	5M	3057.	3057.	1.0106	3000.	0.9663
75	9	2M	2621.	3263.	1.2724	3000.	1.0480
76	9	3L	2631.	3283.	1.2664	3000.	1.0286
77	13	5M	-3030.	3030.	1.0712	3000.	1.0465
78	16	5M	-1507.	3020.	1.0473	3000.	1.0310

TABLE E-26 ADJUSTED DELTA R MEAN STRAIN DATA AT 500 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 500. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	17	3L	-1249.	3258.	1.2293	3000.	1.0157
80	18	4U	-1031.	3085.	1.0923	3000.	1.0225
81	21	5M	1542.	3101.	1.1305	3000.	1.0454
82	22	1U	1298.	3286.	1.2802	3000.	1.0378
83	23	4U	1015.	2992.	1.0307	3000.	1.0377
84			0.	3400.	1.3540	3500.	1.4405
85	8	6L	3559.	3559.	1.4865	3500.	1.4355
86	13	6L	-3233.	3233.	1.3893	3500.	1.6516
87	16	6L	-1667.	3487.	1.5044	3500.	1.5160
88	17	1U	-1294.	3379.	1.3274	3500.	1.4309
89	17	2M	-1292.	3325.	1.2403	3500.	1.3854
90	21	6L	1786.	3578.	1.4994	3500.	1.4320
91	22	2M	1294.	3300.	1.2512	3500.	1.4210
92	22	3L	1354.	3427.	1.3352	3500.	1.3962
93			0.	4000.	1.8790	4000.	1.8790
94	10	1U	2560.	3832.	1.6870	4000.	1.8313
95	10	2M	2573.	3873.	1.8621	4000.	1.9803
96	10	3L	2643.	3883.	1.8221	4000.	1.9274
97	17	5M	-1674.	4125.	1.9425	4000.	1.8352
98	18	1U	-1316.	4003.	2.0165	4000.	2.0134
99	18	2M	-1335.	3990.	1.8364	4000.	1.8453
100	18	3L	-1326.	3912.	1.7514	4000.	1.8264
101	22	5M	1519.	3849.	1.7813	4000.	1.9167
102	23	1U	1383.	4093.	1.9256	4000.	1.8452
103	23	2M	1383.	4063.	1.9916	4000.	1.9349
104			0.	4300.	2.1410	4500.	2.3132
105	9	6L	3487.	4328.	2.2526	4500.	2.4070
106	17	6L	-1777.	4544.	2.4116	4500.	2.3733
107	18	5M	-1643.	4839.	2.5796	4500.	2.2976
108			0.	5200.	2.8870	5200.	2.8870
109	18	6L	-1738.	5260.	2.9967	5200.	2.9492

TABLE E-27 ADJUSTED DELTA R MEAN STRAIN DATA AT 1000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 1000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0210	1000.	0.0210
2	6	4U	2039.	1007.	0.0386	1000.	0.0369
3	11	4U	-2055.	1036.	0.0577	1000.	0.0461
4	14	4U	-1012.	1012.	0.0265	1000.	0.0246
5	19	4U	996.	998.	0.0180	1000.	0.0182
6			0.	1200.	0.0610	1250.	0.0764
7	6	1U	2661.	1325.	0.1343	1250.	0.0987
8	6	2M	2641.	1303.	0.1413	1250.	0.1133
9	6	3L	2681.	1324.	0.1343	1250.	0.0992
10	11	1U	-2553.	1268.	0.1269	1250.	0.1173
11	11	2M	-2615.	1311.	0.1659	1250.	0.1289
12	11	3L	-2601.	1309.	0.1479	1250.	0.1159
13	14	1U	-1318.	1318.	0.1082	1250.	0.0818
14	14	2M	-1330.	1330.	0.1292	1250.	0.0932
15	14	3L	-1303.	1303.	0.1172	1250.	0.0941
16	19	1U	1324.	1324.	0.1050	1250.	0.0776
17	19	2M	1320.	1320.	0.0920	1250.	0.0689
18	19	3L	1317.	1317.	0.0990	1250.	0.0750
19			0.	1500.	0.1880	1500.	0.1880
20	6	5M	2941.	1459.	0.1915	1500.	0.2163
21	7	4U	2028.	1523.	0.2953	1500.	0.2763
22	11	5M	-3019.	1527.	0.2499	1500.	0.2315
23	12	4U	-2094.	1578.	0.2523	1500.	0.2032
24	14	5M	-1538.	1538.	0.2244	1500.	0.2016
25	15	4U	-1026.	1549.	0.2190	1500.	0.1907
26	19	5M	1519.	1519.	0.2211	1500.	0.2096
27	20	4U	981.	1474.	0.2054	1500.	0.2217
28			0.	1700.	0.3150	1750.	0.3529
29	6	6L	3426.	1711.	0.4152	1750.	0.4532
30	11	6L	-3311.	1622.	0.3360	1750.	0.4553
31	14	6L	-1740.	1740.	0.3982	1750.	0.4075
32	19	6L	1727.	1727.	0.4071	1750.	0.4291
33			0.	2000.	0.5710	2000.	0.5710
34	7	1U	2674.	2024.	0.6242	2000.	0.5995
35	7	2M	2573.	1944.	0.6202	2000.	0.6854
36	7	3L	2554.	1908.	0.5822	2000.	0.6874
37	8	4U	2112.	2112.	0.6988	2000.	0.5815
38	12	1U	-2684.	2018.	0.6132	2000.	0.5944

TABLE E-27 ADJUSTED DELTA R MEAN STRAIN DATA AT 1000 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 1000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	0.6082	2000.	0.5724
40	12	3L	-2640.	1989.	0.5922	2000.	0.6034
41	13	4U	-1990.	1970.	0.5962	2000.	0.6071
42	15	1U	-1287.	1936.	0.5021	2000.	0.5627
43	15	2M	-1275.	1924.	0.5001	2000.	0.5735
44	15	3L	-1278.	1934.	0.5201	2000.	0.5847
45	16	4U	-1030.	2093.	0.6732	2000.	0.5774
46	20	1U	1318.	1981.	0.5653	2000.	0.5840
47	20	2M	1297.	1940.	0.5233	2000.	0.5819
48	20	3L	1243.	1860.	0.4512	2000.	0.5845
49	21	4U	1007.	2004.	0.6094	2000.	0.6048
50			0.	2200.	0.7480	2250.	0.7961
51	7	5M	2958.	2223.	0.8213	2250.	0.8497
52	12	5M	-3194.	2369.	0.8914	2250.	0.7755
53	15	5M	-1529.	2310.	0.8702	2250.	0.8098
54	20	5M	1462.	2192.	0.7674	2250.	0.8252
55			0.	2400.	0.9480	2500.	1.0537
56	8	1U	2708.	2708.	1.2485	2500.	1.0249
57	8	2M	2608.	2608.	1.1565	2500.	1.0400
58	8	3L	2602.	2602.	1.2395	2500.	1.1207
59	9	4U	2005.	2493.	1.1334	2500.	1.1413
60	12	6L	-3365.	2527.	1.2083	2500.	1.1764
61	13	1U	-2666.	2666.	1.2883	2500.	1.0982
62	13	3L	-2584.	2584.	1.2583	2500.	1.1575
63	15	6L	-1740.	2635.	1.3163	2500.	1.1542
64	16	1U	-1306.	2634.	1.2513	2500.	1.0982
65	16	2M	-1302.	2604.	1.1843	2500.	1.0696
66	16	3L	-1329.	2671.	1.2963	2500.	1.0996
67	17	4U	-1054.	2647.	1.2376	2500.	1.0733
68	20	6L	1717.	2558.	1.2584	2500.	1.1874
69	21	1U	1283.	2586.	1.2074	2500.	1.1087
70	21	2M	1307.	2611.	1.2444	2500.	1.1159
71	21	3L	1293.	2592.	1.1824	2500.	1.0794
72	22	4U	1013.	2553.	1.1391	2500.	1.0800
73			0.	3000.	1.6240	3000.	1.6240
74	8	5M	3057.	3057.	1.6268	3000.	1.5609
75	9	2M	2621.	3263.	2.0075	3000.	1.6800
76	9	3L	2631.	3283.	1.9815	3000.	1.6373
77	13	5M	-3030.	3030.	1.6784	3000.	1.6427
78	16	5M	-1507.	3020.	1.6304	3000.	1.6070

TABLE E-27 ADJUSTED DELTA R MEAN STRAIN DATA AT 1000 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 1000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	17	3L	-1249.	3258.	1.9305	3000.	1.6203
80	18	4U	-1031.	3085.	1.7155	3000.	1.6142
81	21	5M	1542.	3101.	1.8046	3000.	1.6792
82	22	1U	1298.	3286.	2.0044	3000.	1.6533
83	23	4U	1015.	2992.	1.6391	3000.	1.6493
84			0.	3400.	2.1080	3500.	2.2295
85	8	6L	3559.	3559.	2.3067	3500.	2.2351
86	13	6L	-3233.	3233.	2.1235	3500.	2.4848
87	16	6L	-1667.	3487.	2.2865	3500.	2.3026
88	17	1U	-1294.	3379.	2.0956	3500.	2.2430
89	17	2M	-1292.	3325.	1.9496	3500.	2.1552
90	21	6L	1786.	3578.	2.3476	3500.	2.2523
91	22	2M	1294.	3300.	1.9664	3500.	2.2070
92	22	3L	1354.	3427.	2.1044	3500.	2.1912
93			0.	4000.	2.8260	4000.	2.8260
94	10	1U	2560.	3832.	2.6573	4000.	2.8576
95	10	2M	2573.	3873.	2.7543	4000.	2.9084
96	10	3L	2643.	3883.	2.7503	4000.	2.8904
97	17	5M	-1674.	4125.	2.9219	4000.	2.7795
98	18	1U	-1316.	4003.	3.0777	4000.	3.0737
99	18	2M	-1335.	3990.	2.7747	4000.	2.7865
100	18	3L	-1326.	3912.	2.6606	4000.	2.7611
101	22	5M	1519.	3849.	2.7055	4000.	2.8868
102	23	1U	1383.	4093.	2.9239	4000.	2.8164
103	23	2M	1383.	4063.	3.1110	4000.	3.0328
104			0.	4300.	3.1690	4500.	3.3876
105	9	6L	3487.	4328.	3.2798	4500.	3.4726
106	17	6L	-1777.	4544.	3.4959	4500.	3.4483
107	18	5M	-1643.	4839.	3.7099	4500.	3.3627
108			0.	5200.	4.0790	5200.	4.0790
109	18	6L	-1738.	5260.	4.2130	5200.	4.1585

TABLE E-28 ADJUSTED DELTA R MEAN STRAIN DATA AT 3000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA AT 3000. CYCLES.							
NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0340	1000.	0.0340
2	6	4U	2039.	1007.	0.0664	1000.	0.0630
3	11	4U	-2055.	1036.	0.0836	1000.	0.0646
4	14	4U	-1012.	1012.	0.0407	1000.	0.0373
5	19	4U	998.	998.	0.0309	1000.	0.0313
6			0.	1200.	0.1160	1250.	0.1493
7	6	1U	2661.	1325.	0.2672	1250.	0.1900
8	6	2M	2641.	1303.	0.2852	1250.	0.2233
9	6	3L	2681.	1324.	0.2722	1250.	0.1947
10	11	1U	-2553.	1268.	0.2189	1250.	0.2036
11	11	2M	-2615.	1311.	0.2899	1250.	0.2191
12	11	3L	-2601.	1309.	0.2569	1250.	0.1960
13	14	1U	-1318.	1318.	0.1893	1250.	0.1389
14	14	2M	-1330.	1330.	0.2333	1250.	0.1625
15	14	3L	-1303.	1303.	0.2183	1250.	0.1711
16	19	1U	1324.	1324.	0.2250	1250.	0.1609
17	19	2M	1320.	1320.	0.1960	1250.	0.1424
18	19	3L	1317.	1317.	0.2110	1250.	0.1550
19			0.	1500.	0.4030	1500.	0.4030
20	6	5M	2941.	1459.	0.3874	1500.	0.4446
21	7	4U	2028.	1523.	0.6632	1500.	0.6157
22	11	5M	-3019.	1527.	0.4608	1500.	0.4232
23	12	4U	-2094.	1578.	0.5198	1500.	0.4092
24	14	5M	-1538.	1538.	0.4286	1500.	0.3803
25	15	4U	-1026.	1549.	0.4512	1500.	0.3870
26	19	5M	1519.	1519.	0.4820	1500.	0.4542
27	20	4U	981.	1474.	0.4577	1500.	0.4989
28			0.	1700.	0.7070	1750.	0.7941
29	6	6L	3426.	1711.	0.8613	1750.	0.9416
30	11	6L	-3311.	1622.	0.6851	1750.	0.9400
31	14	6L	-1740.	1740.	0.7903	1750.	0.8091
32	19	6L	1727.	1727.	0.8802	1750.	0.9285
33			0.	2000.	1.2670	2000.	1.2670
34	7	1U	2674.	2024.	1.3193	2000.	1.2727
35	7	2M	2573.	1944.	1.3163	2000.	1.4407
36	7	3L	2554.	1908.	1.2403	2000.	1.4436
37	8	4U	2112.	2112.	1.4600	2000.	1.2459
38	12	1U	-2684.	2018.	1.2515	2000.	1.2173

TABLE E-28 ADJUSTED DELTA R MEAN STRAIN DATA AT 3000 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 3000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	1.2535	2000.	1.1882
40	12	3L	-2640.	1989.	1.2155	2000.	1.2359
41	13	4U	-1990.	1990.	1.2413	2000.	1.2614
42	15	1U	-1287.	1936.	1.0533	2000.	1.1679
43	15	2M	-1275.	1924.	1.0443	2000.	1.1826
44	15	3L	-1278.	1934.	1.0823	2000.	1.2035
45	16	4U	-1030.	2093.	1.3722	2000.	1.2012
46	20	1U	1318.	1981.	1.2215	2000.	1.2575
47	20	2M	1297.	1940.	1.1305	2000.	1.2444
48	20	3L	1243.	1860.	0.9945	2000.	1.2636
49	21	4U	1007.	2004.	1.2976	2000.	1.2889
50			0.	2200.	1.6380	2250.	1.7248
51	7	5M	2958.	2223.	1.6674	2250.	1.7150
52	12	5M	-3194.	2369.	1.7929	2250.	1.5984
53	15	5M	-1529.	2310.	1.7535	2250.	1.6524
54	20	5M	1462.	2192.	1.5898	2250.	1.6885
55			0.	2400.	1.9410	2500.	2.1162
56	8	1U	2708.	2708.	2.4248	2500.	2.0667
57	8	2M	2608.	2608.	2.2718	2500.	2.0841
58	8	3L	2602.	2602.	2.4038	2500.	2.2147
59	9	4U	2005.	2493.	2.2034	2500.	2.2160
60	12	6L	-3365.	2527.	2.3207	2500.	2.2706
61	13	1U	-2666.	2666.	2.4596	2500.	2.1610
62	13	3L	-2584.	2584.	2.4126	2500.	2.2543
63	15	6L	-1740.	2635.	2.5056	2500.	2.2520
64	16	1U	-1306.	2634.	2.4045	2500.	2.1628
65	16	2M	-1302.	2604.	2.2945	2500.	2.1123
66	16	3L	-1329.	2671.	2.4825	2500.	2.1725
67	17	4U	-1054.	2647.	2.4148	2500.	2.1513
68	20	6L	1717.	2558.	2.4557	2500.	2.3424
69	21	1U	1283.	2586.	2.3917	2500.	2.2316
70	21	2M	1307.	2611.	2.4457	2500.	2.2385
71	21	3L	1293.	2592.	2.3236	2500.	2.1579
72	22	4U	1013.	2553.	2.2173	2500.	2.1233
73			0.	3000.	2.9960	3000.	2.9960
74	8	5M	3057.	3057.	3.0021	3000.	2.9060
75	9	2M	2621.	3263.	3.6038	3000.	3.1360
76	9	3L	2631.	3283.	3.4928	3000.	3.0097
77	13	5M	-3030.	3030.	3.0897	3000.	3.0378
78	16	5M	-1507.	3020.	2.9926	3000.	2.9588

TABLE E-28 ADJUSTED DELTA R MEAN STRAIN DATA AT 3000 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 3000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	17	3L	-1249.	3258.	3.4579	3000.	3.0158
80	18	4U	-1031.	3085.	3.0940	3000.	2.9496
81	21	5M	1542.	3101.	3.2950	3000.	3.1138
82	22	1U	1298.	3286.	3.5668	3000.	3.0693
83	23	4U	1015.	2992.	3.0344	3000.	3.0494
84			0.	3400.	3.6680	3500.	3.8225
85	13	6L	-3233.	3233.	3.6658	3500.	4.1158
86	16	6L	-1657.	3437.	3.8999	3500.	3.9200
87	17	1U	-1294.	3379.	3.8140	3500.	4.0098
88	17	2M	-1292.	3325.	3.4869	3500.	3.7541
89	21	6L	1786.	3578.	4.0600	3500.	3.9381
90			0.	4000.	4.5340	4000.	4.5340
91	10	1U*	2560.	3832.	4.8549	4000.	5.1207
92	10	2M	2573.	3873.	4.3268	4000.	4.5029
93	10	3L	2643.	3883.	4.4788	4000.	4.6450
94	17	5M	-1674.	4125.	4.6902	4000.	4.5219
95	18	1U	-1316.	4003.	5.3643	4000.	5.3592
96	18	2M	-1335.	3990.	4.5101	4000.	4.5242
97	18	3L	-1326.	3912.	4.3561	4000.	4.4760
98	23	1U	1383.	4093.	4.8304	4000.	4.6996
99	23	2M	1383.	4063.	5.5565	4000.	5.4540
100			0.	4300.	4.9290	4500.	5.1749
101	17	6L	-1777.	4544.	5.3743	4500.	5.3209
102			0.	5200.	5.9220	5200.	5.9220
103	18	6L	-1738.	5260.	6.2065	5200.	6.1484

* Sensor has failed

TABLE E-29 ADJUSTED DELTA R MEAN STRAIN DATA AT 10000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 10000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0590	1000.	0.0590
2	6	4U	2039.	1007.	0.1193	1000.	0.1125
3	11	4U	-2055.	1036.	0.1256	1000.	0.0942
4	14	4U	-1012.	1012.	0.0649	1000.	0.0589
5	19	4U	998.	998.	0.0570	1000.	0.0579
6			0.	1200.	0.2360	1250.	0.3097
7	6	1U	2661.	1325.	0.5672	1250.	0.3942
8	6	2M	2641.	1303.	0.6083	1250.	0.4683
9	6	3L	2681.	1324.	0.5793	1250.	0.4049
10	11	1U	-2553.	1268.	0.3929	1250.	0.3578
11	11	2M	-2615.	1311.	0.5480	1250.	0.4063
12	11	3L	-2601.	1309.	0.4859	1250.	0.3640
13	14	1U	-1318.	1318.	0.3784	1250.	0.2720
14	14	2M	-1330.	1330.	0.4734	1250.	0.3218
15	14	3L	-1303.	1303.	0.4384	1250.	0.3379
16	19	1U	1324.	1324.	0.5101	1250.	0.3567
17	19	2M	1320.	1320.	0.4381	1250.	0.3113
18	19	3L	1317.	1317.	0.4751	1250.	0.3418
19			0.	1500.	0.8840	1500.	0.8840
20	6	5M	2941.	1459.	0.8224	1500.	0.9468
21	7	4U	2028.	1523.	1.3419	1500.	1.2441
22	11	5M	-3019.	1527.	0.9099	1500.	0.8342
23	12	4U	-2094.	1578.	1.1048	1500.	0.8674
24	14	5M	-1538.	1538.	0.8908	1500.	0.7890
25	15	4U	-1026.	1549.	0.9672	1500.	0.8275
26	19	5M	1519.	1519.	1.0632	1500.	1.0008
27	20	4U	981.	1474.	1.0221	1500.	1.1162
28			0.	1700.	1.5470	1750.	1.7288
29	6	6L	3426.	1711.	1.7405	1750.	1.8953
30	11	6L	-3311.	1622.	1.3642	1750.	1.8538
31	14	6L	-1740.	1740.	1.5965	1750.	1.6328
32	19	6L	1727.	1727.	1.8024	1750.	1.8963
33			0.	2000.	2.4700	2000.	2.4700
34	7	2M	2573.	1944.	2.4934	2000.	2.6210
35	7	3L	2554.	1908.	2.3814	2000.	2.5870
36	8	4U	2112.	2112.	2.7362	2000.	2.4941
37	12	1U	-2684.	2018.	2.4077	2000.	2.3704
38	12	2M	-2705.	2036.	2.4167	2000.	2.3441

TABLE E-29 ADJUSTED DELTA R MEAN STRAIN DATA AT 10000 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA AT 10000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	3L	-2640.	1989.	2.3617	2000.	2.3840
40	13	4U	-1990.	1990.	2.4298	2000.	2.4521
41	15	1U	-1287.	1936.	2.1165	2000.	2.2405
42	15	2M	-1275.	1924.	2.1025	2000.	2.2511
43	15	3L	-1278.	1934.	2.1625	2000.	2.2927
44	16	4U	-1030.	2093.	2.6225	2000.	2.4273
45	20	1U	1318.	1981.	2.4059	2000.	2.4454
46	20	2M	1297.	1940.	2.2508	2000.	2.3735
47	20	3L	1243.	1860.	2.0228	2000.	2.3007
48	21	4U	1007.	2004.	2.4890	2000.	2.4795
49			0.	2200.	3.0150	2250.	3.1256
50	7	5M	2958.	2223.	2.9904	2250.	3.0497
51	12	5M	-3194.	2369.	3.1571	2250.	2.9135
52	15	5M	-1529.	2310.	3.1667	2250.	3.0381
53	20	5M	1462.	2192.	2.9252	2250.	3.0506
54			0.	2400.	3.4540	2500.	3.6701
55	8	2M	2608.	2608.	3.7981	2500.	3.5742
56	8	3L	2602.	2602.	3.9411	2500.	3.7201
57	9	4U	2005.	2493.	3.6884	2500.	3.7032
58	12	6L	-3365.	2527.	3.8980	2500.	3.8387
59	13	1U	-2666.	2666.	4.0660	2500.	3.7113
60	13	3L	-2584.	2584.	3.9690	2500.	3.7837
61	15	6L	-1740.	2635.	4.0979	2500.	3.8010
62	16	1U	-1306.	2634.	3.9779	2500.	3.6916
63	16	2M	-1302.	2604.	3.8828	2500.	3.6629
64	16	3L	-1329.	2671.	4.1389	2500.	3.7672
65	17	4U	-1054.	2647.	4.0254	2500.	3.7105
66	20	6L	1717.	2558.	4.0511	2500.	3.9186
67	21	1U	1283.	2586.	3.9451	2500.	3.7572
68	21	2M	1307.	2611.	4.0541	2500.	3.8089
69	21	3L	1293.	2592.	3.8660	2500.	3.6696
70	22	4U	1013.	2553.	3.7709	2500.	3.6576
71			0.	3000.	4.6970	3000.	4.6970
72	8	5M	3057.	3057.	4.6175	3000.	4.5109
73	9	2M	2621.	3263.	5.3595	3000.	4.8487
74	9	3L	2631.	3283.	5.0954	3000.	4.5771
75	13	5M	-3030.	3030.	4.7473	3000.	4.6900
76	16	5M	-1507.	3020.	4.6690	3000.	4.6310
77	17	3L	-1249.	3258.	5.1944	3000.	4.7069
78	18	4U	-1031.	3085.	4.7026	3000.	4.5440

TABLE E-29 ADJUSTED DELTA R MEAN STRAIN DATA AT 10000 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 10000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	21	5M	1542.	3101.	4.9584	3000.	4.7610
80	22	1U	1298.	3286.	5.3692	3000.	4.8184
81	23	4U	1015.	2992.	4.6972	3000.	4.7138
82			0.	3400.	5.4360	3500.	5.6080
83	13	6L	-3233.	3233.	5.3523	3500.	5.8426
84	16	6L	-1667.	3487.	5.5913	3500.	5.6130
85	17	1U	-1294.	3379.	6.1816	3500.	6.4198
86	17	2M	-1292.	3325.	5.2394	3500.	5.5402
87	21	6L	1786.	3578.	5.9104	3500.	5.7762
88			0.	4000.	6.3900	4000.	6.3900
89	10	2M	2573.	3873.	5.5433	4000.	5.7104
90	18	2M	-1335.	3990.	6.3387	4000.	6.3533
91	18	3L	-1326.	3912.	6.0886	4000.	6.2128
92			0.	4300.	6.7970	4500.	7.0433
93			0.	5200.	*******	5200.	*******

TABLE E-30 ADJUSTED DELTA R MEAN STRAIN DATA AT 30000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA AT 30000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.0980	1000.	0.0980
2	6	4U	2039.	1007.	0.2034	1000.	0.1905
3	11	4U	-2055.	1036.	0.1897	1000.	0.1376
4	14	4U	-1012.	1012.	0.0972	1000.	0.0872
5	19	4U	998.	998.	0.0999	1000.	0.1017
6			0.	1200.	0.4330	1250.	0.5828
7	6	1U	2661.	1325.	1.0154	1250.	0.6987
8	6	2M	2641.	1303.	1.0924	1250.	0.8341
9	6	3L	2681.	1324.	1.0374	1250.	0.7182
10	11	1U	-2553.	1268.	0.6710	1250.	0.6089
11	11	2M	-2615.	1311.	0.9441	1250.	0.6937
12	11	3L	-2601.	1309.	0.8461	1250.	0.6284
13	14	1U	-1318.	1318.	0.6866	1250.	0.4889
14	14	2M	-1330.	1330.	0.8576	1250.	0.5772
15	14	3L	-1303.	1303.	0.7966	1250.	0.6088
16	19	1U	1324.	1324.	0.9328	1250.	0.6461
17	19	2M	1320.	1320.	0.8098	1250.	0.5700
18	19	3L	1317.	1317.	0.8838	1250.	0.6301
19			0.	1500.	1.6470	1500.	1.6470
20	6	5M	2941.	1459.	1.4396	1500.	1.6437
21	7	4U	2028.	1523.	2.2350	1500.	2.0847
22	11	5M	-3019.	1527.	1.5611	1500.	1.4413
23	12	4U	-2094.	1578.	1.8551	1500.	1.4899
24	14	5M	-1538.	1538.	1.5752	1500.	1.4092
25	15	4U	-1026.	1549.	1.7075	1500.	1.4806
26	19	5M	1519.	1519.	1.8227	1500.	1.7236
27	20	4U	981.	1474.	1.8515	1500.	2.0108
28			0.	1700.	2.5410	1750.	2.7240
29	6	6L	3426.	1711.	2.7537	1750.	2.9048
30	11	6L	-3311.	1622.	2.2144	1750.	2.6741
31	14	6L	-1740.	1740.	2.5988	1750.	2.6356
32	19	6L	1727.	1727.	2.8244	1750.	2.9164
33			0.	2000.	3.6170	2000.	3.6170
34	7	1U*	2674.	2024.	1.6392	2000.	1.6033
35	7	2M	2573.	1944.	3.6796	2000.	3.8899
36	7	3L	2554.	1908.	3.5506	2000.	3.8971
37	8	4U	2112.	2112.	3.9508	2000.	3.5802
38	12	1U	-2684.	2018.	3.5811	2000.	3.5205

* Sensor has failed

TABLE E-30 ADJUSTED DELTA R MEAN STRAIN DATA AT 30000 CYCLES (CONTINUED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 30000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	2M	-2705.	2036.	3.5501	2000.	3.4344
40	12	3L	-2640.	1989.	3.5541	2000.	3.5909
41	13	4U	-1990.	1990.	3.6554	2000.	3.6922
42	15	1U	-1287.	1936.	3.3048	2000.	3.5215
43	15	2M	-1275.	1924.	3.2968	2000.	3.5588
44	15	3L	-1278.	1934.	3.3828	2000.	3.6109
45	16	4U	-1030.	2093.	3.8961	2000.	3.5870
46	20	1U	1318.	1981.	3.6863	2000.	3.7531
47	20	2M	1297.	1940.	3.5352	2000.	3.7506
48	20	3L	1243.	1860.	3.2172	2000.	3.7252
49	21	4U	1007.	2004.	3.6785	2000.	3.6632
50			0.	2200.	4.2000	2250.	4.3475
51	7	5M	2958.	2223.	4.2566	2250.	4.3368
52	12	5M	-3194.	2369.	4.3875	2250.	4.0799
53	15	5M	-1529.	2310.	4.4531	2250.	4.2857
54	20	5M	1462.	2192.	4.2457	2250.	4.4205
55			0.	2400.	4.7460	2500.	4.9656
56	8	2M	2608.	2608.	5.0385	2500.	4.8128
57	8	3L	2602.	2602.	5.1825	2500.	4.9618
58	9	4U	2005.	2493.	4.9425	2500.	4.9573
59	12	6L	-3365.	2527.	5.1383	2500.	5.0795
60	13	1U	-2666.	2666.	5.3794	2500.	5.0203
61	13	3L	-2584.	2584.	5.1884	2500.	5.0048
62	15	6L	-1740.	2635.	5.3673	2500.	5.0708
63	16	1U	-1306.	2634.	5.2569	2500.	4.9685
64	16	2M	-1302.	2604.	5.5550	2500.	5.3160
65	16	3L	-1329.	2671.	5.6230	2500.	5.2364
66	17	4U	-1054.	2647.	5.3222	2500.	5.0044
67	20	6L	1717.	2558.	5.4095	2500.	5.2758
68	21	1U	1283.	2586.	5.1834	2500.	5.0021
69	21	2M	1307.	2611.	5.3825	2500.	5.1350
70	21	3L	1293.	2592.	5.1384	2500.	4.9404
71	22	4U	1013.	2553.	5.3288	2500.	5.2079
72			0.	3000.	6.0060	3000.	6.0060
73	8	5M	3057.	3057.	5.8260	3000.	5.7182
74	9	2M	2621.	3263.	6.5930	3000.	6.0795
75	13	5M	-3030.	3030.	5.9998	3000.	5.9419
76	16	5M	-1507.	3020.	6.2519	3000.	6.2114
77	17	3L	-1249.	3258.	6.6049	3000.	6.0986
78	18	4U	-1031.	3085.	6.0665	3000.	5.9022

TABLE E-30 ADJUSTED DELTA R MEAN STRAIN DATA AT 30000 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA AT 30000. CYCLES.							
NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
79	21	5M	1542.	3101.	6.3759	3000.	6.1717
80	23	4U	1015.	2992.	6.0377	3000.	6.0547
81			0.	3400.	6.7670	3500.	6.9476
82	13	6L	-3233.	3233.	6.8707	3500.	7.3925
83	17	2M	-1292.	3325.	6.7089	3500.	7.0313
84			0.	4000.	*******	4000.	*******
85	10	2M*	2573.	3873.	5.2508	4000.	5.3942
86			0.	4300.	*******	4500.	*******
87			0.	5200.	*******	5200.	*******

* Sensor has failed

TABLE E-31 ADJUSTED DELTA R MEAN STRAIN DATA AT 100,000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 100000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.1600	1000.	0.1600
2	6	4U	2039.	1037.	0.3177	1000.	0.2977
3	11	4U	-2055.	1036.	0.2772	1000.	0.2022
4	14	4U	-1012.	1012.	0.1589	1000.	0.1428
5	19	4U	998.	998.	0.1683	1000.	0.1712
6			0.	1200.	0.7200	1250.	0.9485
7	6	1U	2661.	1325.	1.5246	1250.	1.0661
8	6	2M	2641.	1303.	1.6616	1250.	1.2831
9	6	3L	2681.	1324.	1.5726	1250.	1.1059
10	11	1U	-2553.	1268.	1.0829	1250.	0.9867
11	11	2M	-2615.	1311.	1.5500	1250.	1.1539
12	11	3L	-2601.	1309.	1.3820	1250.	1.0394
13	14	1U	-1318.	1318.	1.1610	1250.	0.8389
14	14	2M	-1330.	1330.	1.3960	1250.	0.9555
15	14	3L	-1303.	1303.	1.3170	1250.	1.0179
16	19	1U	1324.	1324.	1.4854	1250.	1.0451
17	19	2M	1320.	1320.	1.3134	1250.	0.9384
18	19	3L	1317.	1317.	1.5414	1250.	1.1146
19			0.	1500.	2.4520	1500.	2.4520
20	6	5M	2941.	1459.	2.1249	1500.	2.3685
21	7	4U	2028.	1523.	3.2877	1500.	3.1028
22	11	5M	-3019.	1527.	2.4110	1500.	2.2561
23	12	4U	-2094.	1578.	2.7962	1500.	2.3268
24	14	5M	-1538.	1538.	2.4369	1500.	2.2210
25	15	4U	-1026.	1549.	2.5312	1500.	2.2472
26	19	5M	1519.	1519.	2.7258	1500.	2.6022
27	20	4U	981.	1474.	2.6867	1500.	2.8751
28			0.	1700.	3.3820	1750.	3.5862
29	6	6L	3426.	1711.	4.0321	1750.	4.2178
30	11	6L	-3311.	1622.	3.1826	1750.	3.7295
31	14	6L	-1740.	1740.	3.6192	1750.	3.6624
32	19	6L	1727.	1727.	3.8769	1750.	3.9833
33			0.	2000.	4.5670	2000.	4.5670
34	7	2M	2573.	1944.	4.7545	2000.	4.9867
35	7	3L	2554.	1908.	4.5814	2000.	4.9622
36	8	4U	2112.	2112.	5.0241	2000.	4.6136
37	12	1U	-2684.	2018.	4.8023	2000.	4.7322
38	12	2M	-2705.	2036.	4.6293	2000.	4.4990

TABLE E-31 ADJUSTED DELTA R MEAN STRAIN DATA AT 100,000 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 100000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
39	12	3L	-2640.	1989.	4.8463	2000.	4.8895
40	13	4U	-1990.	1990.	5.3724	2000.	5.4139
41	15	1U	-1287.	1936.	5.0290	2000.	5.3108
42	15	2M	-1275.	1924.	4.3748	2000.	4.6715
43	15	3L	-1278.	1934.	4.5949	2000.	4.8596
44	16	4U	-1030.	2093.	5.2773	2000.	4.9133
45	20	1U	1318.	1981.	4.7411	2000.	4.8150
46	20	2M	1297.	1940.	4.7201	2000.	4.9661
47	20	3L	1243.	1860.	4.2310	2000.	4.7965
48	21	4U	1007.	2004.	4.8420	2000.	4.8247
49			0.	2200.	5.2730	2250.	5.4358
50	7	5M	2958.	2223.	5.7600	2250.	5.8556
51	12	5M	-3194.	2369.	6.6099	2250.	6.1957
52	15	5M	-1529.	2310.	5.7300	2250.	5.5385
53	20	5M	1462.	2192.	5.3723	2250.	5.5665
54			0.	2400.	5.8880	2500.	6.1585
55	8	2M	2608.	2608.	6.0131	2500.	5.7663
56	9	4U	2005.	2493.	6.1997	2500.	6.2176
57	12	6L	-3365.	2527.	6.4166	2500.	6.3472
58	13	3L	-2584.	2534.	6.2899	2500.	6.0842
59	15	6L	-1740.	2635.	6.5754	2500.	6.2460
60	16	1U	-1306.	2634.	6.5455	2500.	6.2196
61	17	4U	-1054.	2647.	6.8536	2500.	6.4840
62	20	6L	1717.	2558.	6.4965	2500.	6.3466
63	21	1U	1283.	2586.	6.5405	2500.	6.3223
64			0.	3000.	*******	3000.	*******
65	8	5M	3057.	3057.	6.7979	3000.	6.7284
66			0.	3400.	*******	3500.	*******
67			0.	4000.	*******	4000.	*******
68			0.	4300.	*******	4500.	*******
69			0.	5200.	*******	5200.	*******

TABLE E-32 ADJUSTED DELTA R MEAN STRAIN DATA AT 500,000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 500000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.2360	1000.	0.2360
2	6	4U	2039.	1007.	0.4792	1000.	0.4463
3	11	4U	-2055.	1036.	0.4643	1000.	0.3295
4	14	4U	-1012.	1012.	0.2780	1000.	0.2472
5	19	4U	998.	998.	0.2779	1000.	0.2832
6			0.	1200.	1.1500	1250.	1.5164
7	6	1U	2661.	1325.	2.1949	1250.	1.5503
8	6	2M	2641.	1303.	2.4289	1250.	1.8861
9	6	3L	2681.	1324.	2.3139	1250.	1.6432
10	11	1U	-2553.	1268.	1.7921	1250.	1.6345
11	11	3L	-2601.	1309.	2.2762	1250.	1.7232
12	14	1U	-1318.	1318.	1.9552	1250.	1.4245
13	14	2M	-1330.	1330.	2.1852	1250.	1.5125
14	14	3L	-1303.	1303.	2.1032	1250.	1.6348
15	19	1U	1324.	1324.	2.0844	1250.	1.4806
16	19	2M	1320.	1320.	2.0144	1250.	1.4520
17			0.	1500.	3.3870	1500.	3.3870
18	6	5M	2941.	1459.	2.9944	1500.	3.3186
19	7	4U	2028.	1523.	4.4374	1500.	4.2136
20	11	5M	-3019.	1527.	3.6473	1500.	3.4380
21	14	5M	-1538.	1538.	3.6552	1500.	3.3689
22	15	4U	-1026.	1549.	3.8086	1500.	3.4333
23	19	5M	1519.	1519.	3.8398	1500.	3.6837
24	20	4U	981.	1474.	3.8429	1500.	4.0948
25			0.	1700.	5.1910	1750.	5.6541
26	6	6L	3426.	1711.	5.1194	1750.	5.4660
27	11	6L	-3311.	1622.	4.4949	1750.	5.6847
28	14	6L	-1740.	1740.	4.8775	1750.	4.9620
29	19	6L	1727.	1727.	5.1231	1750.	5.3277
30			0.	2000.	*******	2000.	*******
31	7	2M	2573.	1944.	6.1033	2000.	6.4864
32	7	3L	2554.	1908.	5.5942	2000.	6.2007
33	8	4U	2112.	2112.	6.5488	2000.	5.9093
34	12	2M	-2705.	2036.	6.5650	2000.	6.3364
35	15	2M	-1275.	1924.	6.3798	2000.	6.9405
36	20	1U	1318.	1931.	6.2428	2000.	6.3649
37	20	2M	1297.	1940.	6.2628	2000.	6.6812
38	20	3L	1243.	1860.	5.6257	2000.	6.6301
39			0.	2200.	*******	2250.	*******
40			0.	2400.	*******	2500.	*******

TABLE E-32 ADJUSTED DELTA R MEAN STRAIN DATA AT 500,000 CYCLES (CONCLUDED)

ADJUSTED DELTA R MEAN STRAIN DATA
AT 500000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
41	8	2M	2608.	2608.	6.8957	2500.	6.7340
42			0.	3000.	*******	3000.	*******
43			0.	3400.	*******	3500.	*******
44			0.	4000.	*******	4000.	*******
45			0.	4300.	*******	4500.	*******
46			0.	5200.	*******	5200.	*******

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FATIGUE SENSOR EVALUATION PROGRAM LABORATORY TEST REPORT.(U)

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TABLE E-33 ADJUSTED DELTA R MEAN STRAIN DATA AT 1,000,000 CYCLES

ADJUSTED DELTA R MEAN STRAIN DATA
AT 1000000. CYCLES.

NO.	SPEC.	SEN	MEAN STRAIN	ALT. STRAIN	DELTA R	ADJ. ALT. STRAIN	ADJ. DELTA R
1			0.	1000.	0.2730	1000.	0.2730
2	6	4U	2039.	1007.	0.5541	1000.	0.5159
3	11	4U	-2055.	1036.	0.5136	1000.	0.3633
4	14	4U	-1012.	1012.	0.3245	1000.	0.2884
5			0.	1200.	1.3210	1250.	1.7424
6	6	1U	2661.	1325.	2.5870	1250.	1.8291
7	6	2M	2641.	1303.	2.8460	1250.	2.2116
8	6	3L	2681.	1324.	2.8160	1250.	2.0022
9	11	1U	-2553.	1268.	2.0883	1250.	1.9051
10	11	3L	-2601.	1309.	2.6254	1250.	1.9890
11	14	1U	-1318.	1318.	2.4131	1250.	1.7599
12	14	2M	-1330.	1330.	2.6241	1250.	1.8186
13	14	3L	-1303.	1303.	2.5421	1250.	1.9769
14			0.	1500.	4.2730	1500.	4.2730
15	6	5M	2941.	1459.	3.3495	1500.	3.7039
16	7	4U	2028.	1523.	5.9856	1500.	5.6934
17	11	5M	-3019.	1527.	4.2976	1500.	4.0580
18	14	5M	-1538.	1538.	4.5190	1500.	4.1753
19	15	4U	-1026.	1549.	4.8955	1500.	4.4270
20	20	4U	931.	1474.	5.4155	1500.	5.7620
21			0.	1700.	6.2000	1750.	6.3937
22	6	6L	3426.	1711.	5.7245	1750.	5.8560
23	11	6L	-3311.	1622.	5.6612	1750.	6.3279
24	14	6L	-1740.	1740.	5.7436	1750.	5.7717
25			0.	2000.	*******	2000.	*******
26	7	3L	2554.	1908.	6.1805	2000.	5.8975
27			0.	2200.	*******	2250.	*******
28			0.	2400.	*******	2500.	*******
29			0.	3000.	*******	3000.	*******
30			0.	3400.	*******	3500.	*******
31			0.	4000.	*******	4000.	*******
32			0.	4300.	*******	4500.	*******
33			0.	5200.	*******	5200.	*******

APPENDIX F

SAMPLE OF RAW TEST DATA AND TEST DATA ANALYSIS (SPECIMEN #6)

F.1 INTRODUCTION

Appendix F presents a sample of the test data collected by the laboratory test series including both the raw data collected and basic calculated values. Raw test data collected from the laboratory tests was transcribed from test data sheets to IBM computer cards; resulting computer output was used to present test data in a concise manner as shown by Tables F-1 and F-3 (for specimen #6).

Raw data was used to calculate basic fatigue sensor parameters:

a) Resistance change

b) Multiplier performance

Resistance change calculations consist of the difference between fatigue sensor initial resistance reading and readings at periodic intervals of applied cycles (as shown by Table F-2).

Multiplier performance calculations are based on load cycle data collected during applied strain cycles. Data calculations are used to verify the behavior of the Micro-Measurements FM multiplier; effective strain amplification and strain compensation are calculated. Table F-4 shows multiplier performance calculations for specimen #6.

F.2 EQUATIONS FOR PARAMETER CALCULATIONS

F.2.1 Constant Amplitude Specimens - #1 thru #23 and #33

1. Sensor response calculations (Table F-2)

Delta R (resistance change calculation)

Delta R = $R_N - R_i + TKCR_N$

Where:

Delta R = Resistance change at N cycles corrected for temperature variation

R_N = Current fatigue sensor reading at N cycles (ohms)

R_i = Initial fatigue sensor reading at zero cycles (ohms)

$TKCR_N$ = Temperature correction at N cycles

Temperature correction ($TKCR_N$) is calculated as follows: (see section 6.1)

$$TKCR_N = (T_N - T_i)\ (T_K + .00023\ DELR_N)$$

Where:

T_N = Specimen temperature at N cycles (°F)

T_i = Initial specimen temperature at zero cycles (°F)

TK = Temperature correction constant for each multiplier at $DELR_N = 0$

$$DELR_N = R_N - R_i$$

2. Load cycle response calculations (Table F-4)

The terms used in the load cycle calculations are as follows:

S.G. No. 1 and No. 2 = Strain readings from strain gages mounted on the specimen adjacent to the fatigue sensor.

Specimen strain = Average strain indicated by specimen strain gages.

Mult. strain = Amplified strain indicated by fatigue sensor multiplier (either strain gage or fatigue sensor element).

Test multiplier = Effective strain amplification calculated by comparing specimen strain with multiplied strain.

Target multiplier = Multiplier ratio established by manufacturer.

Percent target = Percent deviation of test multiplier from target multiplier.

Specimen alt. and mean strain = Calculated applied strain cycles using specimen strain gage data at maximum and minimum applied load levels.

Strain gage and fatigue sensor alt. strain = Calculated amplified strain cycles applied to strain gage and fatigue sensor elements of fatigue sensor multiplier assembly.

Specimen strain is calculated and is the average value of strain indicated by S.G. No. 1 and S.G. No. 2.

$$\text{Specimen strain} = \frac{\text{S.G. No. 1} + \text{S.G. No. 2}}{2}$$

Where:

$$\text{S.G. (strain)} = \text{S.G.}_{\text{(loaded)}} - \text{S.G.}_{\text{(zero load)}}$$

NOTE: For maximum and mean load levels, S.G. strain is calculated using initial S.G. reading, while minimum load level is calculated using final S.G. reading.

$$\text{Mult. strain} = \text{FSG}_{\text{(load)}} - \text{FSG}_{\text{(zero load)}}$$

Where:

FSG = Fatigue sensor strain gage

NOTE: In case of fatigue sensor strain gage malfunction, the fatigue sensor element itself is used to calculate multiplied strain.

$$\text{Test mult.} = \frac{\text{Mult. strain}}{\text{Specimen strain}}$$

$$\text{Percent target} = 100 \left[\frac{\text{Test mult.} - \text{target mult.}}{\text{Target mult.}}\right]$$

3. Multiplier stability calculations

Ohms variation from initial zero = Composite sensor reading (at load) - Composite sensor reading (no load)

$$\text{Load effect ratio} = \frac{\text{Ohms variation} + DELR_N}{DELR_N}$$

Where:

$$DELR_N = R_N - R_i \text{ (see Delta R calculation discussion)}$$

F.2.2 Spectrum Loaded Specimens - #24 and #25

The spectrum loaded specimens were analyzed using the same equations as the constant amplitude specimens (see F.2.1 above).

F.2.3 Ambient Temperature Cycle Specimen - #26

The ambient temperature cycle specimen was analyzed using the same equations as the constant amplitude specimens (see F.2.1). In addition, the resistance change due to ambient temperature variation calculations (Table 38) were made using the Delta R equation without a temperature correction as follows:

$$\text{Delta R} = R_N - R_i$$

F.2.4 Cyclic Temperature Specimens #27 thru #30

The cyclic temperature specimens were analyzed using the same equations as the constant amplitude specimens, except that the resistance change (ΔR) calculations used no correction for temperature variation.

F.2.5 Temperature Induced Strain Cycle Specimens #31 and #32

The equations used to calculate the resistance change (ΔR) values are the same as those used for other specimens. No temperature variation correction was used.

The equations used to analyze the apparent strain cycles (see Table 44) were as follows:

$$\text{Apparent strain (S.G.)} = FSG_{(\text{at temp})} - FSG_{(50°F)}$$

$$\text{Apparent strain (F.S.)} = FATS_{(\text{at temp})} - FATS_{(50°F)}$$

Where:

FSG = Fatigue sensor strain gage reading ($\mu\varepsilon$)

FATS = Fatigue sensor element strain reading ($\mu\varepsilon$)

NOTE: The 50°F readings used above are the final 50° readings for each cycle.

$$\text{Apparent alternating strain (S.G.)} = \frac{\text{Apparent strain (SG)}_{(+150°F)} - \text{Apparent strain (SG)}_{(-50°F)}}{2}$$

$$\text{Apparent alternating strain (F.S.)} = \frac{\text{Apparent strain (FS)}_{(+150°F)} - \text{Apparent strain (FS)}_{(-50°F)}}{2}$$

TABLE F-1 SENSOR RESPONSE RAW TEST DATA FOR SPECIMEN #6

SENSOR RESPONSE RAW TEST DATA   SPECIMEN NO. = 6 (PAGE 1 OF 2)

ALT STRAIN = 500   MEAN STRAIN = 1000   ZERO TEMP = 75.5

READ NO.	TEMP	CYCLES	SENSOR NO.1U COMP SENS	SENSOR NO.1U F.S. ONLY	SENSOR NO.1U S.G. ONLY	SENSOR NO.2M COMP SENS	SENSOR NO.2M F.S. ONLY	SENSOR NO.2M S.G. ONLY	SENSOR NO.3L COMP SENS	SENSOR NO.3L F.S. ONLY	SENSOR NO.3L S.G. ONLY
0.	75.5	0.	-0.541	0.877	1.383	-0.304	0.942	1.214	-0.611	0.788	1.366
1.	76.2	10.	-0.536	0.882	1.387	-0.300	0.949	1.217	-0.606	0.796	1.369
2.	76.2	25.	-0.532	0.892	1.390	-0.296	0.958	1.220	-0.602	0.804	1.372
3.	76.2	50.	-0.526	0.900	1.390	-0.289	0.966	1.222	-0.596	0.812	1.373
4.	76.3	100.	-0.513	0.912	1.390	-0.274	0.980	1.222	-0.582	0.824	1.374
5.	77.0	150.	-0.503	0.919	1.387	-0.264	0.987	1.216	-0.573	0.831	1.368
6.	77.0	200.	-0.494	0.927	1.390	-0.255	0.997	1.220	-0.563	0.839	1.370
7.	77.0	300.	-0.450	0.943	1.389	-0.240	1.012	1.219	-0.550	0.854	1.369
8.	77.3	500.	-0.458	0.965	1.387	-0.216	1.036	1.218	-0.527	0.876	1.368
9.	77.3	700.	-0.436	0.986	1.388	-0.193	1.058	1.217	-0.505	0.897	1.368
10.	77.3	1000.	-0.407	1.013	1.387	-0.163	1.086	1.218	-0.477	0.924	1.368
11.	76.0	1500.	-0.372	1.048	1.385	-0.124	1.124	1.215	-0.440	0.960	1.365
12.	76.0	2000.	-0.337	1.082	1.388	-0.088	1.160	1.216	-0.405	0.995	1.367
13.	76.7	3000.	-0.274	1.146	1.388	-0.019	1.228	1.216	-0.339	1.060	1.366
14.	76.8	5000.	-0.170	1.244	1.386	0.095	1.334	1.215	-0.233	1.162	1.365
15.	76.8	7000.	-0.081	1.332	1.388	0.189	1.428	1.216	-0.141	1.252	1.366
16.	76.4	10000.	0.026	1.440	1.388	0.304	1.546	1.217	-0.032	1.362	1.366
17.	76.4	15000.	0.176	1.584	1.385	0.463	1.700	1.214	0.122	1.510	1.364
18.	76.4	20000.	0.296	1.705	1.385	0.594	1.831	1.214	0.246	1.632	1.364
19.	75.4	25000.	0.396	1.801	1.386	0.702	1.936	1.214	0.347	1.732	1.364
20.	76.6	30000.	0.474	1.880	1.383	0.788	2.021	1.212	0.426	1.811	1.362
21.	76.6	40000.	0.596	2.000	1.382	0.920	2.154	1.210	0.552	1.936	1.360
22.	76.6	50000.	0.694	2.100	1.386	1.030	2.264	1.216	0.655	2.040	1.365
23.	76.6	65000.	0.801	2.205	1.385	1.148	2.382	1.214	0.766	2.150	1.365
24.	76.6	80000.	0.886	2.289	1.385	1.246	2.479	1.214	0.857	2.240	1.364
25.	77.3	100000.	0.983	2.384	1.384	1.357	2.588	1.212	0.961	2.343	1.362
25.	74.7	100000.	0.982	2.373	1.375	1.357	2.580	1.206	0.959	2.330	1.353
26.	76.3	150000.	1.125	2.532	1.383	1.523	2.759	1.213	1.113	2.500	1.363
27.	77.9	200000.	1.212	2.629	1.388	1.624	2.871	1.220	1.207	2.605	1.370
28.	78.4	250000.	1.310	2.721	1.391	1.738	2.978	1.220	1.317	2.709	1.370
29.	78.2	300000.	1.384	2.798	1.390	1.823	3.065	1.220	1.400	2.792	1.371
30.	78.4	400000.	1.539	2.939	1.382	1.996	3.227	1.214	1.570	2.952	1.365
31.	78.5	500000.	1.653	3.050	1.378	2.124	3.351	1.210	1.702	3.083	1.362
32.	77.2	750000.	1.856	3.255	1.383	2.346	3.577	1.215	1.977	3.357	1.364
32.	77.6	850000.	1.938	3.333	1.382	2.433	3.657	1.212	2.067	3.444	1.363
32.	78.3	950000.	2.007	3.407	1.377	2.504	3.732	1.207	2.158	3.541	1.360
33.	78.4	1000000.	2.045	3.446	1.377	2.541	3.772	1.208	2.204	3.584	1.360

TABLE F-1 SENSOR RESPONSE RAW TEST DATA FOR SPECIMEN #6 (CONCLUDED)

SENSOR RESPONSE RAW TEST DATA   SPECIMEN NO. = 6 (PAGE 2 OF 2)

ALT STRAIN = 500   MEAN STRAIN = 1000   ZERO TEMP = 75.5

READ NO.	TEMP	CYCLES	SENSOR NO.4U COMP SENS	SENSOR NO.4U F.S. ONLY	SENSOR NO.4U S.G. ONLY	SENSOR NO.5M COMP SENS	SENSOR NO.5M F.S. ONLY	SENSOR NO.5M S.G. ONLY	SENSOR NO.6L COMP SENS	SENSOR NO.6L F.S. ONLY	SENSOR NO.6L S.G. ONLY
0.	75.5	0.	-0.291	1.020	1.278	-0.996	0.405	1.357	-0.326	0.872	1.165
1.	76.2	10.	-0.292	1.016	1.273	-0.988	0.388	1.341	-0.313	0.858	1.139
2.	76.2	25.	-0.291	1.020	1.275	-0.981	0.399	1.344	-0.298	0.878	1.142
3.	76.2	50.	-0.288	1.022	1.275	-0.973	0.409	1.366	-0.281	0.899	1.145
4.	76.3	100.	-0.282	1.027	1.277	-0.953	0.430	1.351	-0.245	0.938	1.150
5.	77.0	150.	-0.280	1.031	1.277	-0.942	0.442	1.348	-0.215	0.965	1.147
6.	77.0	200.	-0.276	1.034	1.278	-0.928	0.455	1.350	-0.189	0.999	1.148
7.	77.0	300.	-0.273	1.038	1.279	-0.909	0.475	1.350	-0.146	1.034	1.148
8.	77.3	500.	-0.267	1.043	1.276	-0.877	0.506	1.347	-0.073	1.106	1.146
9.	77.3	700.	-0.261	1.050	1.277	-0.856	0.537	1.348	-0.003	1.174	1.146
10.	77.3	1000.	-0.253	1.056	1.277	-0.805	0.575	1.347	0.089	1.260	1.144
11.	76.0	1500.	-0.247	1.064	1.276	-0.750	0.629	1.345	0.214	1.384	1.140
12.	76.0	2000.	-0.238	1.072	1.278	-0.702	0.679	1.346	0.328	1.497	1.142
13.	76.7	3000.	-0.225	1.085	1.279	-0.609	0.776	1.350	0.535	1.708	1.148
14.	76.8	5000.	-0.207	1.100	1.276	-0.456	0.921	1.347	0.860	2.027	1.143
15.	76.8	7000.	-0.188	1.118	1.279	-0.328	1.049	1.349	1.118	2.284	1.146
16.	76.4	10000.	-0.172	1.136	1.278	-0.174	1.204	1.348	1.414	2.583	1.146
17.	76.4	15000.	-0.145	1.161	1.279	0.036	1.408	1.347	1.787	2.948	1.142
18.	76.4	20000.	-0.124	1.184	1.278	0.204	1.575	1.346	2.061	3.222	1.140
19.	76.4	25000.	-0.102	1.204	1.280	0.337	1.706	1.347	2.268	3.426	1.140
20.	76.6	30000.	-0.088	1.218	1.278	0.443	1.811	1.344	2.427	3.582	1.136
21.	76.6	40000.	-0.064	1.244	1.279	0.608	1.977	1.344	2.673	3.826	1.135
22.	76.6	50000.	-0.040	1.268	1.283	0.740	2.109	1.348	2.861	4.014	1.139
23.	76.6	65000.	-0.018	1.291	1.284	0.883	2.250	1.348	3.108	4.256	1.138
24.	76.6	80000.	0.002	1.310	1.283	0.998	2.365	1.347	3.392	4.540	1.137
25.	77.3	100000.	0.026	1.331	1.282	1.128	2.492	1.345	3.705	4.848	1.134
25.	74.7	100000.	0.030	1.323	1.271	1.121	2.489	1.349	3.664	4.824	1.149
26.	76.3	150000.	0.056	1.367	1.285	1.322	2.697	1.351	4.031	5.185	1.144
27.	77.9	200000.	0.071	1.396	1.293	1.443	2.826	1.357	4.260	5.430	1.144
28.	78.4	250000.	0.101	1.417	1.292	1.574	2.951	1.356	4.322	5.475	1.142
29.	78.2	300000.	0.119	1.437	1.293	1.670	3.049	1.358	4.387	5.540	1.143
30.	78.4	400000.	0.160	1.470	1.288	1.860	3.228	1.350	4.638	5.774	1.134
31.	78.5	500000.	0.187	1.500	1.289	1.997	3.360	1.348	4.792	5.924	1.127
32.	77.2	750000.	0.229	1.537	1.285	2.205	3.585	1.363	5.026	6.185	1.151
32.	77.6	850000.	0.246	1.562	1.295	2.275	3.643	1.352	5.315	6.441	1.131
32.	78.3	950000.	0.255	1.573	1.294	2.326	3.698	1.349	5.370	6.498	1.124
33.	78.4	1000000.	0.262	1.584	1.294	2.352	3.725	1.349	5.397	6.528	1.123

TABLE F-2 RESISTANCE CHANGE DATA FOR SPECIMEN #6

SPECIMEN NO. = 6

ALT STRAIN = 500 MEAN STRAIN = 1000 ZERO TEMP = 75.5

INTIAL ZERO READING	1U	2M	3L	4U	5M	6L
	-0.541	-0.304	-0.611	-0.291	-0.996	-0.326

CALCULATED VALUES OF DELTA R

READ	CYCLES	TEMP	1U	2M	3L	4U	5M	6L
1.	10.	76.2	0.005	0.004	0.005	-0.000	0.008	0.013
2.	25.	76.2	0.009	0.008	0.009	0.000	0.015	0.028
3.	50.	76.2	0.015	0.015	0.015	0.003	0.023	0.045
4.	100.	76.3	0.028	0.030	0.029	0.009	0.043	0.081
5.	150.	77.0	0.038	0.040	0.038	0.011	0.054	0.111
6.	200.	77.0	0.047	0.049	0.048	0.015	0.068	0.137
7.	300.	77.0	0.061	0.064	0.061	0.018	0.087	0.180
8.	500.	77.3	0.083	0.088	0.084	0.024	0.119	0.253
9.	700.	77.3	0.105	0.111	0.106	0.030	0.140	0.323
10.	1000.	77.3	0.134	0.141	0.134	0.038	0.191	0.415
11.	1500.	76.0	0.169	0.180	0.171	0.044	0.246	0.540
12.	2000.	76.0	0.204	0.216	0.206	0.053	0.294	0.654
13.	3000.	76.7	0.267	0.285	0.272	0.066	0.387	0.861
14.	5000.	76.8	0.371	0.399	0.378	0.084	0.540	1.186
15.	7000.	76.8	0.460	0.493	0.470	0.103	0.668	1.444
16.	10000.	76.4	0.567	0.608	0.579	0.119	0.822	1.740
17.	15000.	76.4	0.717	0.767	0.733	0.146	1.032	2.113
18.	20000.	76.4	0.837	0.898	0.857	0.167	1.200	2.387
19.	25000.	76.4	0.937	1.006	0.958	0.189	1.333	2.594
20.	30000.	76.6	1.015	1.092	1.037	0.203	1.439	2.753
21.	40000.	76.6	1.137	1.224	1.163	0.227	1.604	2.999
22.	50000.	76.6	1.235	1.334	1.266	0.251	1.736	3.187
23.	65000.	76.6	1.342	1.452	1.377	0.273	1.879	3.434
24.	80000.	76.6	1.427	1.550	1.468	0.293	1.994	3.719
25.	100000.	77.3	1.524	1.661	1.572	0.317	2.125	4.032
25.	100000.	74.7	1.522	1.660	1.569	0.320	2.116	3.989
26.	150000.	76.3	1.666	1.827	1.724	0.347	2.318	4.357
27.	200000.	77.9	1.754	1.929	1.819	0.363	2.440	4.588
28.	250000.	78.4	1.852	2.043	1.929	0.393	2.572	4.651
29.	300000.	78.2	1.926	2.128	2.012	0.411	2.668	4.716
30.	400000.	78.4	2.081	2.301	2.182	0.452	2.858	4.967
31.	500000.	78.5	2.195	2.430	2.314	0.479	2.995	5.121
32.	750000.	77.2	2.398	2.651	2.589	0.520	3.202	5.354
32.	850000.	77.6	2.480	2.738	2.679	0.537	3.273	5.643
32.	950000.	78.3	2.550	2.810	2.771	0.547	3.324	5.699
33.	1000000.	78.4	2.588	2.847	2.817	0.554	3.350	5.727

NOTE-- CALCULATED VALUES OF DELTA R HAVE BEEN CORRECTED TO THE ZERO TEMPERATURE

TABLE F-3 LOAD RESPONSE RAW TEST DATA FOR SPECIMEN #6

LOAD RESPONSE RAW TEST DATA   SPECIMEN NO. = 6 (PAGE 1 OF 3)

APPL. LOAD	SEN. NO.	LOAD CYCLE NO. 1 NO. OF APPLIED CYCLES= 0.					LOAD CYCLE NO. 2 NO. OF APPLIED CYCLES= 100.					LOAD CYCLE NO. 3 NO. OF APPLIED CYCLES= 1000.				
		FATIGUE SENSOR DATA			STRAIN GAGE DATA		FATIGUE SENSOR DATA			STRAIN GAGE DATA		FATIGUE SENSOR DATA			STRAIN GAGE DATA	
(LBS)		COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2	COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2	COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2
	1U	-0.541	4085.	6465.	725	-121	-0.513	4254.	6525.	746	-96	-0.407	4726.	6500.	741	-97
	2M	-0.304	4396.	5672.	188	-204	-0.274	4578.	5730.	192	-176	-0.163	5076.	5701.	189	-177
0	3L	-0.611	3676.	6382.	866	-887	-0.582	3842.	6438.	876	-856	-0.477	4316.	6410.	874	-859
	4U	-0.291	4765.	5988.	-254	-417	-0.282	4794.	5976.	-251	-447	-0.253	4928.	5972.	-244	-450
	5M	-0.996	1888.	6338.	271	247	-0.953	2002.	6330.	265	224	-0.805	2689.	6310.	266	233
	6L	-0.326	4075.	5442.	66	-18	-0.245	4383.	5392.	62	-10	0.089	5898.	5361.	65	-10
	1U	-0.542	8095.	10473.	2233	1420	-0.515	8260.	10518.	2240	1419	-0.408	8718.	10473.	2240	1414
	2M	-0.302	8390.	9646.	1692	1357	-0.272	8571.	9687.	1686	1350	-0.159	9053.	9640.	1680	1344
9470	3L	-0.611	7700.	10409.	2390	674	-0.586	7865.	10450.	2390	671	-0.478	8326.	10404.	2387	665
	4U	-0.273	7874.	8994.	1242	1035	-0.252	7962.	9042.	1249	1036	-0.231	8091.	9022.	1256	1032
	5M	-0.997	6174.	10680.	1761	1689	-0.958	6420.	10737.	1766	1696	-0.805	7105.	10706.	1769	1706
	6L	-0.325	9124.	10494.	1539	1435	-0.241	9577.	10540.	1542	1439	0.098	11095.	10501.	1547	1442
	1U	-0.549	6754.	9164.	1732	915	-0.522	6944.	9239.	1741	916	-0.415	7362.	9153.	1766	911
	2M	-0.308	7054.	8350.	1196	842	-0.282	7253.	8418.	1190	842	-0.168	7700.	8332.	1187	838
6330	3L	-0.618	6353.	9094.	1881	167	-0.592	6540.	9170.	1882	166	-0.485	6966.	9077.	1883	161
	4U	-0.282	6824.	7986.	732	530	-0.274	6942.	8069.	745	535	-0.244	7027.	8007.	753	534
	5M	-1.004	4676.	9215.	1258	1196	-0.968	4926.	9319.	1266	1202	-0.815	5590.	9237.	1268	1211
	6L	-0.337	7359.	8784.	1044	949	-0.255	7831.	8872.	1049	951	0.082	9304.	8790.	1054	956
	1U	-0.549	5430.	7844.	1254	416	-0.522	5605.	7905.	1251	413	-0.417	6046.	7836.	1244	412
	2M	-0.310	5734.	7038.	700	337	-0.283	5923.	7095.	692	336	-0.171	6388.	7029.	689	334
3190	3L	-0.619	5026.	7769.	1382	-338	-0.593	5198.	7828.	1381	-340	-0.486	5642.	7757.	1380	-347
	4U	-0.299	5772.	6970.	242	40	-0.281	5886.	7047.	252	47	-0.252	5982.	7002.	258	45
	5M	-1.003	3214.	7747.	764	708	-0.966	3467.	7837.	765	713	-0.818	4124.	7777.	768	722
	6L	-0.337	5634.	7059.	557	470	-0.256	6087.	7134.	557	472	0.079	7576.	7073.	561	472
	1U	-0.541	4101.	6482.	744	-97	-0.515	4243.	6496.	742	-100	-0.410	4716.	6484.	740	-99
	2M	-0.305	4410.	5688.	198	-178	-0.277	4561.	5699.	190	-180	-0.165	5060.	5684.	186	-180
0	3L	-0.610	3690.	6397.	873	-859	-0.585	3828.	6409.	874	-860	-0.478	4304.	6389.	871	-862
	4U	-0.292	4730.	5941.	-262	-450	-0.286	4803.	5972.	-245	-450	-0.255	4934.	5972.	-244	-448
	5M	-0.995	1779.	6264.	259	219	-0.958	1982.	6305.	266	235	-0.807	2680.	6298.	266	232
	6L	-0.329	3945.	5327.	57	-12	-0.248	4358.	5355.	64	-9	0.088	5879.	5340.	65	-10

NOTE--COMPOSITE SENSOR DATA = OHMS
--ALL OTHER DATA = MICRO-STRAIN

TABLE F-3 LOAD RESPONSE RAW TEST DATA FOR SPECIMEN #6 (CONTINUED)

LOAD RESPONSE RAW TEST DATA SPECIMEN NO. = 6 (PAGE 2 OF 3)

APPL. LOAD	SEN. NO.	LOAD CYCLE NO. 4, NO. OF APPLIED CYCLES= 3000.					LOAD CYCLE NO. 5, NO. OF APPLIED CYCLES= 10000.					LOAD CYCLE NO. 6, NO. OF APPLIED CYCLES= 30000.				
		FATIGUE SENSOR DATA			STRAIN GAGE DATA		FATIGUE SENSOR DATA			STRAIN GAGE DATA		FATIGUE SENSOR DATA			STRAIN GAGE DATA	
(LBS)		COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2	COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2	COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2
	1U	-0.274	5350.	6497.	727	-105	0.026	6732.	6490.	735	-97	0.474	8804.	6487.	736	-97
	2M	-0.019	5740.	5695.	182	-188	0.304	7220.	5690.	189	-179	0.788	9476.	5687.	188	-178
0	3L	-0.339	4946.	6394.	865	-872	-0.032	6362.	6388.	870	-862	0.426	8489.	6388.	870	-864
	4U	-0.225	5064.	5973.	-252	-458	-0.172	5300.	5968.	-245	-450	-0.088	5702.	5984.	-243	-450
	5M	-0.609	3615.	6314.	263	226	-0.174	5626.	6306.	272	231	0.443	8490.	6303.	271	233
	6L	0.535	7985.	5368.	64	-12	1.414	12076.	5357.	72	0	2.427	16781.	5336.	72	-3
	1U	-0.272	9345.	10480.	2226	1409	0.029	10722.	10456.	2223	1412	0.478	12810.	10454.	2226	1410
	2M	-0.014	9720.	9643.	1678	1337	0.310	11200.	9620.	1682	1338	0.795	13461.	9625.	1683	1339
9470	3L	-0.338	8965.	10405.	2382	656	-0.030	10380.	10386.	2384	658	0.430	12516.	10389.	2384	656
	4U	-0.204	8236.	9035.	1252	1029	-0.150	8469.	9022.	1256	1034	-0.066	8878.	9042.	1260	1034
	5M	-0.606	8037.	10724.	1769	1705	-0.171	10066.	10714.	1773	1711	0.450	12947.	10718.	1774	1715
	6L	0.544	13180.	10520.	1547	1443	1.428	17298.	10502.	1553	1452	2.449	22044.	10492.	1555	1456
	1U	-0.280	7987.	9160.	1735	912	0.020	9384.	9153.	1730	910	0.469	11458.	9144.	1732	910
	2M	-0.022	8367.	8334.	1186	838	0.300	9865.	8330.	1187	833	0.785	12110.	8322.	1180	836
6330	3L	-0.345	7606.	9078.	1884	159	-0.040	9032.	9071.	1878	153	0.420	11155.	9066.	1879	153
	4U	-0.214	7170.	8028.	759	538	-0.161	7420.	8026.	755	536	-0.077	7815.	8033.	760	538
	5M	-0.616	6525.	9259.	1274	1217	-0.182	8560.	9262.	1270	1216	0.437	11426.	9257.	1270	1217
	6L	0.529	11393.	8809.	1060	961	1.409	15514.	8808.	1059	964	2.428	20242.	8788.	1060	968
	1U	-0.282	6667.	7836.	1260	413	0.018	8054.	7827.	1246	410	0.464	10134.	7824.	1236	408
	2M	-0.026	7049.	7024.	690	333	0.296	8540.	7020.	689	330	0.780	10793.	7019.	690	332
3190	3L	-0.348	6273.	7748.	1381	-349	-0.042	7697.	7744.	1374	-352	0.416	9823.	7744.	1376	-352
	4U	-0.222	6118.	7004.	260	49	-0.170	6370.	7010.	260	44	-0.088	6767.	7022.	262	46
	5M	-0.618	5046.	7785.	773	726	-0.186	7078.	7794.	771	725	0.433	9944.	7793.	772	727
	6L	0.522	9648.	7074.	567	480	1.402	13757.	7084.	566	480	2.416	18469.	7067.	567	482
	1U	-0.276	5375.	6536.	739	-100	0.024	6716.	6478.	734	-97	0.470	8813.	6491.	736	-99
	2M	-0.020	5769.	5732.	187	-183	0.300	7208.	5680.	190	-181	0.784	9481.	5692.	188	-182
0	3L	-0.340	4970.	6437.	871	-866	-0.036	6350.	6380.	869	-864	0.423	8492.	6393.	869	-864
	4U	-0.225	5114.	6030.	-243	-450	-0.174	5308.	5973.	-244	-450	-0.090	5718.	5997.	-243	-450
	5M	-0.610	3627.	6363.	271	235	-0.179	5609.	6300.	270	232	0.439	8494.	6313.	272	233
	6L	0.529	8024.	5401.	72	-3	1.407	12041.	5348.	70	-4	2.420	16788.	5347.	72	1

NOTE--COMPOSITE SENSOR DATA = OHMS
--ALL OTHER DATA = MICRO-STRAIN

TABLE F-3 LOAD RESPONSE RAW TEST DATA FOR SPECIMEN #6 (CONCLUDED)

LOAD RESPONSE RAW TEST DATA   SPECIMEN NO. = 6 (PAGE 3 OF 3)

APPL. LOAD	SEN. NO.	LOAD CYCLE NO. 7 NO. OF APPLIED CYCLES= 100000.					LOAD CYCLE NO. 8 NO. OF APPLIED CYCLES= 300000.					LOAD CYCLE NO. 9 NO. OF APPLIED CYCLES=1000000.				
		FATIGUE SENSOR DATA			STRAIN GAGE DATA		FATIGUE SENSOR DATA			STRAIN GAGE DATA		FATIGUE SENSOR DATA			STRAIN GAGE DATA	
(LBS)		COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2	COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2	COMP	F.S. ONLY	S.G. ONLY	S.G. NO.1	S.G. NO.2
	1U	0.982	11096.	6415.	731	-112	1.384	13162.	6560.	729	-106	2.045	16126.	6484.	723	-109
	2M	1.357	12054.	5625.	180	-191	1.823	14428.	5764.	180	-186	2.541	17650.	5689.	173	-194
0	3L	0.959	10890.	6315.	861	-881	1.400	13141.	6474.	870	-875	2.204	16770.	6395.	864	-881
	4U	0.030	6170.	5924.	-243	-447	0.119	6750.	6078.	-238	-450	0.262	7404.	6057.	-234	-454
	5M	1.121	11629.	6292.	272	235	1.670	14359.	6412.	274	236	2.352	17439.	6349.	277	236
	6L	3.664	22532.	5356.	70	8	4.387	26043.	5412.	72	22	5.397	30458.	5310.	72	13
	1U	0.982	15079.	10390.	2216	1402	1.388	17195.	10526.	2229	1409	2.186	20717.	10496.	2230	1407
	2M	1.361	16045.	9583.	1669	1325	1.830	18479.	9727.	1678	1332	2.577	21747.	9612.	1673	1332
9470	3L	0.959	14913.	10337.	2374	646	1.435	17379.	10486.	2391	650	2.286	21140.	10365.	2385	645
	4U	0.049	9337.	8997.	1258	1034	0.139	9949.	9153.	1247	1040	0.286	10550.	9084.	1274	1034
	5M	1.123	16071.	10720.	1776	1708	1.676	18896.	10861.	1784	1720	2.508	22559.	10740.	1782	1714
	6L	4.645	32237.	10520.	1554	1456	6.270	40190.	10566.	1562	1484	9.495	0.	10381.	1567	1475
	1U	0.974	13721.	9085.	1719	899	1.378	15686.	9130.	1729	907	2.346	19978.	9109.	1723	902
	2M	1.350	14682.	8283.	1176	825	1.818	16952.	8340.	1181	831	2.564	20390.	8312.	1176	836
6330	3L	0.948	13546.	9019.	1869	143	0.000	0.	9080.	1884	145	0.000	0.	9050.	1878	140
	4U	0.036	8278.	7995.	756	536	0.128	8798.	8069.	770	542	0.274	9494.	8086.	774	532
	5M	1.109	14539.	9262.	1274	1213	1.662	17187.	9303.	1281	1223	2.490	21004.	9279.	1284	1216
	6L	4.427	29455.	8819.	1059	965	5.313	33540.	8780.	1065	995	8.594	47710.	8694.	1061	987
	1U	0.968	12406.	7775.	1225	402	1.371	14359.	7319.	1231	404	2.056	17535.	7796.	1262	403
	2M	1.345	13363.	6981.	676	321	1.810	15617.	7032.	683	328	2.550	19040.	7011.	678	323
3190	3L	0.945	12216.	7698.	1365	-363	1.467	14728.	7755.	1382	-361	0.000	0.	7735.	1372	-367
	4U	0.026	7237.	6987.	251	43	0.118	7748.	7058.	273	57	0.263	8456.	7085.	274	41
	5M	1.103	13050.	7794.	773	723	1.650	15671.	7826.	780	730	2.346	18904.	7816.	778	729
	6L	3.841	25080.	7099.	566	484	4.409	27772.	7060.	571	510	5.488	32731.	7001.	570	500
	1U	0.974	11176.	6492.	728	-107	1.375	13018.	6478.	735	-103	2.050	16153.	6465.	732	-108
	2M	1.348	12137.	5694.	178	-191	1.812	14268.	5692.	180	-187	2.545	17668.	5675.	172	-184
0	3L	0.950	10974.	6394.	878	-877	1.397	13030.	6392.	872	-874	2.264	17058.	6382.	861	-876
	4U	0.022	6234.	6007.	-245	-450	0.114	6682.	6014.	-235	-453	0.260	7400.	6052.	-232	-455
	5M	1.106	11681.	5363.	271	233	1.652	14173.	5336.	276	236	2.342	17391.	6335.	280	236
	6L	3.816	23411.	5410.	71	3	4.367	25798.	5341.	72	21	5.377	30448.	5301.	74	15

NOTE--COMPOSITE SENSOR DATA = OHMS
--ALL OTHER DATA = MICRO-STRAIN

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6

LOAD CYCLE DATA CALCULATIONS   SPECIMEN NO. 6 (PAGE 1 OF 9)

APPLIED CYCLES = 0.   ALT. STRAIN = 500   MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1508.0	1541.0	1524.5	4008.0	2.62	2.60	1.11
2M	1504.0	1561.0	1532.5	3974.0	2.59	2.60	-0.26
3L	1524.0	1561.0	1542.5	4027.0	2.61	2.60	0.41
4U	1496.0	1452.0	1474.0	3006.0	2.03	2.00	1.96
5M	1490.0	1442.0	1466.0	4342.0	2.96	3.00	-1.27
6L	1473.0	1453.0	1463.0	5052.0	3.45	3.50	-1.33
----MEAN APPLIED LOAD = 6330							
1U	1007.0	1036.0	1021.5	2699.0	2.64	2.60	1.62
2M	1008.0	1046.0	1027.0	2678.0	2.60	2.60	0.29
3L	1015.0	1054.0	1034.5	2712.0	2.62	2.60	0.82
4U	986.0	947.0	966.5	1998.0	2.06	2.00	3.36
5M	987.0	949.0	968.0	2877.0	2.97	3.00	-0.92
6L	978.0	967.0	972.5	3342.0	3.43	3.50	-1.81
----MIN APPLIED LOAD = 3190							
1U	510.0	513.0	511.5	1362.0	2.66	2.60	2.41
2M	502.0	515.0	508.5	1350.0	2.65	2.60	2.11
3L	509.0	521.0	515.0	1372.0	2.66	2.60	2.46
4U	504.0	490.0	497.0	1029.0	2.07	2.00	3.52
5M	505.0	489.0	497.0	1483.0	2.98	3.00	-0.53
6L	500.0	482.0	491.0	1732.0	3.52	3.50	0.78

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	506.5	1018.0	1323.0	1340.5
2M	512.0	1020.5	1312.0	1335.0
3L	513.7	1028.7	1327.5	1344.0
4U	488.5	985.5	988.5	1033.5
5M	484.5	981.5	1429.5	1425.5
6L	486.0	977.0	1660.0	1680.0

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS

2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	-0.541	-0.001	-0.008	-0.008	0.000
2M	-0.304	0.001	-0.004	-0.005	-0.000
3L	-0.611	0.000	-0.006	-0.008	0.001
4U	-0.291	0.018	0.009	0.001	-0.001
5M	-0.996	-0.001	-0.008	-0.006	0.001
6L	-0.326	0.000	-0.010	-0.010	-0.003
	DELTA R*	LOAD EFFECT RATIO			
1U	0.000	-0.001	-0.008	-0.008	0.000
2M	0.000	0.001	-0.004	-0.005	-0.000
3L	0.000	0.000	-0.006	-0.008	0.001
4U	0.000	0.018	0.009	0.001	-0.001
5M	0.000	-0.001	-0.008	-0.006	0.001
6L	0.000	0.000	-0.010	-0.010	-0.003

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS — SPECIMEN NO. 6 (PAGE 2 OF 9)

APPLIED CYCLES = 100. ALT. STRAIN = 500 MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1494.0	1515.0	1504.5	3993.0	2.65	2.60	2.07
2M	1494.0	1526.0	1510.0	3957.0	2.62	2.60	0.78
3L	1514.0	1527.0	1520.5	4012.0	2.63	2.60	1.48
4U	1500.0	1483.0	1491.5	3066.0	2.05	2.00	2.78
5M	1501.0	1472.0	1486.5	4407.0	2.96	3.00	-1.17
6L	1480.0	1449.0	1464.5	5148.0	3.51	3.50	0.43
----MEAN APPLIED LOAD = 6330							
1U	995.0	1012.0	1003.5	2714.0	2.70	2.60	4.02
2M	998.0	1018.0	1008.0	2688.0	2.66	2.60	2.56
3L	1006.0	1022.0	1014.0	2732.0	2.69	2.60	3.62
4U	996.0	982.0	989.0	2093.0	2.11	2.00	5.81
5M	1001.0	978.0	989.5	2989.0	3.02	3.00	0.69
6L	987.0	961.0	974.0	3480.0	3.57	3.50	2.08
----MIN APPLIED LOAD = 3190							
1U	509.0	513.0	511.0	1409.0	2.75	2.60	6.05
2M	502.0	516.0	509.0	1396.0	2.74	2.60	5.48
3L	507.0	520.0	513.5	1419.0	2.76	2.60	6.28
4U	497.0	497.0	497.0	1075.0	2.16	2.00	8.14
5M	499.0	478.0	488.5	1532.0	3.13	3.00	4.53
6L	493.0	481.0	487.0	1779.0	3.65	3.50	4.37

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	496.7	1007.7	1292.0	1322.0
2M	500.5	1009.5	1280.5	1315.5
3L	503.5	1017.0	1296.5	1326.5
4U	497.2	994.2	995.5	1042.5
5M	499.0	987.5	1437.5	1466.5
6L	488.7	975.7	1684.5	1732.5

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS
2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	-0.513	-0.002	-0.009	-0.009	-0.002
2M	-0.274	0.002	-0.007	-0.009	-0.002
3L	-0.582	-0.004	-0.009	-0.011	-0.003
4U	-0.282	0.019	0.007	0.000	-0.004
5M	-0.953	-0.004	-0.014	-0.013	-0.004
6L	-0.245	0.003	-0.010	-0.011	-0.003
	DELTA R*	LOAD EFFECT RATIO			
1U	0.028	0.928	0.678	0.678	0.928
2M	0.029	1.066	0.733	0.699	0.900
3L	0.029	0.862	0.655	0.620	0.896
4U	0.009	3.222 △	1.888	1.111	0.555
5M	0.042	0.883	0.651	0.697	0.883
6L	0.081	1.049	0.876	0.864	0.962

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

△ High load effect ratio is due to low value of Delta R

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS   SPECIMEN NO. 6 (PAGE 3 OF 9)

APPLIED CYCLES = 1000.   ALT. STRAIN = 500   MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1499.0	1511.0	1505.0	3973.0	2.63	2.60	1.53
2M	1491.0	1521.0	1506.0	3939.0	2.61	2.60	0.59
3L	1513.0	1524.0	1518.5	3994.0	2.63	2.60	1.16
4U	1500.0	1482.0	1491.0	3050.0	2.04	2.00	2.28
5M	1503.0	1473.0	1488.0	4396.0	2.95	3.00	-1.52
6L	1482.0	1452.0	1467.0	5140.0	3.50	3.50	0.10
----MEAN APPLIED LOAD = 6330							
1U	1025.0	1008.0	1016.5	2653.0	2.60	2.60	0.38
2M	998.0	1015.0	1006.5	2631.0	2.61	2.60	0.53
3L	1009.0	1020.0	1014.5	2667.0	2.62	2.60	1.11
4U	997.0	984.0	990.5	2035.0	2.05	2.00	2.72
5M	1002.0	978.0	990.0	2927.0	2.95	3.00	-1.44
6L	989.0	966.0	977.5	3429.0	3.50	3.50	0.22
----MIN APPLIED LOAD = 3190							
1U	504.0	511.0	507.5	1352.0	2.66	2.60	2.46
2M	503.0	514.0	508.5	1345.0	2.64	2.60	1.73
3L	509.0	515.0	512.0	1368.0	2.67	2.60	2.76
4U	502.0	493.0	497.5	1030.0	2.07	2.00	3.51
5M	502.0	490.0	496.0	1479.0	2.98	3.00	-0.60
6L	496.0	482.0	489.0	1733.0	3.54	3.50	1.25

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	498.7	1006.2	1310.5	1331.0
2M	498.7	1007.2	1297.0	1324.5
3L	503.2	1015.2	1313.0	1336.0
4U	496.7	994.2	1010.0	1057.5
5M	496.0	992.0	1458.5	1486.0
6L	489.0	978.0	1703.5	1750.0

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS
2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	-0.407	-0.001	-0.008	-0.010	-0.003
2M	-0.163	0.004	-0.004	-0.007	-0.002
3L	-0.477	-0.000	-0.007	-0.008	-0.000
4U	-0.253	0.021	0.008	0.000	-0.002
5M	-0.805	0.000	-0.009	-0.013	-0.001
6L	0.089	0.009	-0.007	-0.009	-0.000
	DELTA R*	LOAD EFFECT RATIO			
1U	0.133	0.992	0.940	0.925	0.977
2M	0.141	1.028	0.964	0.943	0.985
3L	0.133	0.992	0.940	0.932	0.992
4U	0.037	1.578 △	1.236	1.026	0.947
5M	0.191	1.000	0.947	0.931	0.989
6L	0.415	1.021	0.983	0.975	0.997

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

△ See Note 1

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS SPECIMEN NO. 6 (PAGE 4 OF 9)

APPLIED CYCLES = 3000. ALT. STRAIN = 500 MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1499.0	1514.0	1506.5	3983.0	2.64	2.60	1.66
2M	1496.0	1525.0	1510.5	3948.0	2.61	2.60	0.52
3L	1517.0	1528.0	1522.5	4011.0	2.63	2.60	1.32
4U	1504.0	1487.0	1495.5	3062.0	2.04	2.00	2.37
5M	1506.0	1479.0	1492.5	4410.0	2.95	3.00	-1.50
6L	1483.0	1455.0	1469.0	5152.0	3.50	3.50	0.20
----MEAN APPLIED LOAD = 6330							
1U	1008.0	1017.0	1012.5	2663.0	2.63	2.60	1.15
2M	1004.0	1026.0	1015.0	2639.0	2.60	2.60	0.00
3L	1019.0	1031.0	1025.0	2684.0	2.61	2.60	0.71
4U	1011.0	996.0	1003.5	2055.0	2.04	2.00	2.39
5M	1011.0	991.0	1001.0	2945.0	2.94	3.00	-1.93
6L	996.0	973.0	984.5	3441.0	3.49	3.50	-0.13
----MIN APPLIED LOAD = 3190							
1U	521.0	513.0	517.0	1300.0	2.51	2.60	-3.28
2M	503.0	516.0	509.5	1292.0	2.53	2.60	-2.46
3L	510.0	517.0	513.5	1311.0	2.55	2.60	-1.80
4U	503.0	499.0	501.0	974.0	1.94	2.00	-2.79
5M	502.0	491.0	496.5	1422.0	2.86	3.00	-4.53
6L	495.0	483.0	489.0	1673.0	3.42	3.50	-2.24

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	494.7	1011.7	1341.5	1351.5
2M	500.5	1010.0	1328.0	1350.0
3L	504.5	1018.0	1350.0	1358.0
4U	497.2	998.2	1044.0	1084.0
5M	498.0	994.5	1494.0	1501.5
6L	490.0	979.0	1739.5	1785.5

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS
2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	-0.274	0.002	-0.005	-0.007	-0.001
2M	-0.019	0.004	-0.003	-0.007	-0.001
3L	-0.339	0.000	-0.005	-0.009	-0.000
4U	-0.225	0.021	0.011	0.003	0.000
5M	-0.609	0.003	-0.006	-0.008	-0.000
6L	0.535	0.008	-0.006	-0.013	-0.006
	DELTA R*	LOAD EFFECT RATIO			
1U	0.266	1.007	0.977	0.970	0.992
2M	0.284	1.017	0.989	0.975	0.996
3L	0.272	1.003	0.977	0.966	0.996
4U	0.065	1.318	1.166	1.045	1.000
5M	0.387	1.007	0.981	0.976	0.997
6L	0.861	1.010	0.993	0.984	0.993

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS   SPECIMEN NO. 6 (PAGE 5 OF 9)

APPLIED CYCLES = 10000.   ALT. STRAIN = 500   MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
---MAX APPLIED LOAD = 9470							
1U	1488.0	1509.0	1498.5	3966.0	2.64	2.60	1.79
2M	1493.0	1517.0	1505.0	3930.0	2.61	2.60	0.43
3L	1514.0	1520.0	1517.0	3998.0	2.63	2.60	1.36
4U	1501.0	1484.0	1492.5	3054.0	2.04	2.00	2.31
5M	1501.0	1480.0	1490.5	4408.0	2.95	3.00	-1.42
6L	1481.0	1452.0	1466.5	5145.0	3.50	3.50	0.23
---MEAN APPLIED LOAD = 6330							
1U	995.0	1007.0	1001.0	2663.0	2.66	2.60	2.32
2M	998.0	1012.0	1005.0	2640.0	2.62	2.60	1.03
3L	1008.0	1015.0	1011.5	2683.0	2.65	2.60	2.01
4U	1000.0	986.0	993.0	2058.0	2.07	2.00	3.62
5M	998.0	985.0	991.5	2956.0	2.98	3.00	-0.62
6L	987.0	964.0	975.5	3451.0	3.53	3.50	1.07
---MIN APPLIED LOAD = 3190							
1U	512.0	507.0	509.5	1349.0	2.64	2.60	1.83
2M	499.0	511.0	505.0	1340.0	2.65	2.60	2.05
3L	505.0	512.0	508.5	1364.0	2.68	2.60	3.16
4U	504.0	494.0	499.0	1037.0	2.07	2.00	3.90
5M	501.0	493.0	497.0	1494.0	3.00	3.00	0.20
6L	496.0	484.0	490.0	1736.0	3.54	3.50	1.22

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	494.5	1004.0	1308.5	1326.0
2M	500.0	1005.0	1295.0	1324.0
3L	504.2	1012.7	1317.0	1335.5
4U	496.7	995.7	1008.5	1053.5
5M	496.7	993.7	1457.0	1485.5
6L	488.2	978.2	1704.5	1753.0

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1)STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS

2)LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	0.026	0.003	-0.005	-0.007	-0.002
2M	0.304	0.005	-0.004	-0.008	-0.004
3L	-0.032	0.002	-0.008	-0.009	-0.004
4U	-0.172	0.022	0.011	0.002	-0.002
5M	-0.174	0.003	-0.007	-0.011	-0.004
6L	1.414	0.014	-0.004	-0.011	-0.006
	DELTA R*	LOAD EFFECT RATIO			
1U	0.566	1.005	0.989	0.985	0.996
2M	0.608	1.009	0.993	0.986	0.993
3L	0.578	1.003	0.986	0.982	0.993
4U	0.118	1.184	1.092	1.016	0.983
5M	0.822	1.003	0.990	0.985	0.993
6L	1.740	1.008	0.997	0.993	0.995

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS   SPECIMEN NO. 6 (PAGE 6 OF 9)

APPLIED CYCLES = 30000.   ALT. STRAIN = 500   MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1490.0	1507.0	1498.5	3967.0	2.64	2.60	1.81
2M	1495.0	1517.0	1506.0	3938.0	2.61	2.60	0.57
3L	1514.0	1520.0	1517.0	4001.0	2.63	2.60	1.44
4U	1503.0	1484.0	1493.5	3058.0	2.04	2.00	2.37
5M	1503.0	1482.0	1492.5	4415.0	2.95	3.00	-1.39
6L	1483.0	1459.0	1471.0	5136.0	3.50	3.50	0.14
----MEAN APPLIED LOAD = 6330							
1U	996.0	1007.0	1001.5	2657.0	2.65	2.60	2.03
2M	992.0	1014.0	1003.0	2635.0	2.62	2.60	1.04
3L	1009.0	1017.0	1013.0	2678.0	2.64	2.60	1.67
4U	1003.0	988.0	995.5	2049.0	2.05	2.00	2.91
5M	999.0	984.0	991.5	2954.0	2.97	3.00	-0.68
6L	988.0	971.0	979.5	3452.0	3.52	3.50	0.69
----MIN APPLIED LOAD = 3190							
1U	500.0	507.0	503.5	1333.0	2.64	2.60	1.82
2M	502.0	514.0	508.0	1327.0	2.61	2.60	0.45
3L	507.0	512.0	509.5	1351.0	2.65	2.60	1.98
4U	505.0	496.0	500.5	1025.0	2.04	2.00	2.39
5M	500.0	494.0	497.0	1480.0	2.97	3.00	-0.73
6L	495.0	481.0	488.0	1720.0	3.52	3.50	0.70

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	497.5	1001.0	1317.0	1342.5
2M	499.0	1007.0	1305.5	1336.5
3L	503.7	1013.2	1325.0	1348.0
4U	496.5	997.0	1016.5	1063.5
5M	497.7	994.7	1467.5	1503.5
6L	491.5	979.5	1718.0	1791.0

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS
2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	0.474	0.004	-0.004	-0.009	-0.004
2M	0.788	0.006	-0.003	-0.008	-0.004
3L	0.426	0.003	-0.006	-0.010	-0.003
4U	-0.088	0.022	0.011	0.000	-0.001
5M	0.443	0.007	-0.005	-0.009	-0.004
6L	2.427	0.022	0.001	-0.010	-0.006
	DELTA R*	LOAD EFFECT RATIO			
1U	1.015	1.003	0.995	0.990	0.996
2M	1.092	1.006	0.997	0.992	0.996
3L	1.037	1.003	0.994	0.990	0.997
4U	0.202	1.108	1.054	1.000	0.990
5M	1.439	1.004	0.995	0.993	0.997
6L	2.752	1.007	1.000	0.996	0.997

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS   SPECIMEN NO. 6 (PAGE 7 OF 9)

APPLIED CYCLES = 100000.   ALT. STRAIN = 500   MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1485.0	1514.D	1499.5	3975.0	2.65	2.60	1.95
2M	1489.D	1516.0	1502.5	3958.0	2.63	2.60	1.31
3L	1513.0	1527.0	1520.0	4022.0	2.64	2.60	1.77
4U	1501.D	1481.0	1491.0	3073.0	2.06	2.00	3.05
5M	1504.D	1473.0	1488.5	4428.0	2.97	3.0D	-0.83
6L	1484.D	1448.0	1466.D	5164.0	3.52	3.5D	0.64
----MEAN APPLIED LOAD = 6330							
1U	988.D	1D11.0	999.5	2670.D	2.67	2.60	2.74
2M	996.D	1016.0	1006.D	2658.0	2.64	2.60	1.62
3L	1008.D	1024.0	1016.0	2704.0	2.66	2.60	2.36
4U	999.D	983.0	991.0	2071.D	2.08	2.00	4.49
5M	10D2.0	978.0	990.D	2970.0	3.00	3.0D	D.00
6L	989.0	957.0	973.0	3463.0	3.55	3.50	1.68
----MIN APPLIED LOAD = 3190							
1U	497.0	509.0	503.0	1283.0	2.55	2.60	-1.89
2M	498.D	512.0	5D5.D	1287.D	2.54	2.60	-1.98
3L	487.0	514.0	500.5	1304.0	2.60	2.6D	D.2D
4U	5D6.D	493.D	499.5	980.0	1.96	2.00	-1.90
5M	502.D	49D.0	496.0	1431.D	2.88	3.00	-3.83
6L	495.0	481.0	488.0	1689.0	3.46	3.50	-1.11

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	498.2	10D1.2	1346.0	1376.5
2M	498.7	1D03.7	1335.5	1382.5
3L	509.7	1010.2	1359.0	1390.5
4U	495.7	995.2	1046.5	1082.0
5M	496.2	992.2	1498.5	1536.5
6L	489.0	977.0	1737.5	4D18.0 ⚠

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS
2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	0.982	0.000	-0.008	-0.014	-0.008
2M	1.357	0.003	-0.006	-0.012	-0.009
3L	0.959	0.000	-0.011	-0.014	-0.009
4U	0.030	0.019	0.006	-0.004	-0.007
5M	1.121	0.002	-0.011	-0.017	-0.014
6L	3.664	0.981 ⚠	0.762	0.177	0.152
	DELTA R*	LOAD EFFECT RATIO			
1U	1.523	1.000	0.994	0.990	0.994
2M	1.661	1.002	0.995	0.992	0.994
3L	1.570	1.000	0.992	0.991	0.994
4U	0.320	1.059	1.018	0.987	0.975
5M	2.117	1.000	0.994	0.991	0.992
6L	3.989	1.245	1.191	1.044	1.038

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

⚠ Fatigue sensor element is beyond useful life as a strain gage

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONTINUED)

LOAD CYCLE DATA CALCULATIONS — SPECIMEN NO. 6 (PAGE 8 OF 9)

APPLIED CYCLES = 300000. ALT. STRAIN = 500 MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1500.0	1515.0	1507.5	3966.0	2.63	2.60	1.18
2M	1498.0	1518.0	1508.0	3963.0	2.62	2.60	1.07
3L	1521.0	1525.0	1523.0	4012.0	2.63	2.60	1.31
4U	1485.0	1490.0	1487.5	3075.0	2.06	2.00	3.36
5M	1510.0	1484.0	1497.0	4449.0	2.97	3.00	-0.93
6L	1490.0	1462.0	1476.0	5154.0	3.49	3.50	-0.23
----MEAN APPLIED LOAD = 6330							
1U	1000.0	1013.0	1006.5	2570.0	2.55	2.60	-1.79
2M	1001.0	1017.0	1009.0	2576.0	2.55	2.60	-1.80
3L	1014.0	1020.0	1017.0	2606.0	2.56	2.60	-1.44
4U	1008.0	992.0	1000.0	1991.0	1.99	2.00	-0.45
5M	1007.0	987.0	997.0	2891.0	2.89	3.00	-3.34
6L	993.0	973.0	983.0	3368.0	3.42	3.50	-2.10
----MIN APPLIED LOAD = 3190							
1U	496.0	507.0	501.5	1341.0	2.67	2.60	2.84
2M	503.0	515.0	509.0	1340.0	2.63	2.60	1.25
3L	510.0	513.0	511.5	1363.0	2.66	2.60	2.48
4U	508.0	510.0	509.0	1044.0	2.05	2.00	2.55
5M	504.0	494.0	499.0	1490.0	2.98	3.00	-0.46
6L	499.0	489.0	494.0	1719.0	3.47	3.50	-0.57

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	503.0	1004.5	1312.5	1346.0
2M	499.5	1008.5	1311.5	1351.0
3L	505.7	1017.2	1324.5	1270.0
4U	489.2	998.2	1015.5	1066.5
5M	499.0	998.0	1479.5	1519.5
6L	491.0	985.0	1717.5	6086.5 [3]

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1) STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS

2) LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	1.384	0.003	-0.006	-0.013	-0.008
2M	1.823	0.006	-0.005	-0.013	-0.011
3L	1.400	0.035	-1.400 [5]	0.066	-0.003
4U	0.119	0.020	0.009	-0.001	-0.004
5M	1.670	0.006	-0.007	-0.019	-0.017
6L	4.387	1.683 [3]	0.926	0.022	-0.019
	DELTA R*	LOAD EFFECT RATIO			
1U	1.924	1.002	0.996	0.993	0.995
2M	2.127	1.003	0.997	0.993	0.994
3L	2.011	1.017	0.303 [5]	1.033	0.995
4U	0.409	1.045	1.021	0.997	0.957
5M	2.665	1.002	0.996	0.992	0.993
6L	4.712	1.399	1.196	1.004	0.995

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

[3] See Note 3

[5] Fatigue sensor element is open at mean load level

TABLE F-4 LOAD CYCLE DATA CALCULATIONS FOR SPECIMEN #6 (CONCLUDED)

LOAD CYCLE DATA CALCULATIONS   SPECIMEN NO. 6 (PAGE 9 OF 9)

APPLIED CYCLES = 1000000.   ALT. STRAIN = 500   MEAN STRAIN = 1000

A. MULTIPLIER PERFORMANCE CALCULATIONS FROM LOAD CYCLE

SEN NO.	S.G. NO.1	S.G. NO.2	SPECIMEN STRAIN	MULT STRAIN	TEST MULT	TARG MULT	PECT TARG
----MAX APPLIED LOAD = 9470							
1U	1507.0	1516.0	1511.5	4012.0	2.65	2.60	2.08
2M	1500.0	1526.0	1513.0	3923.0	2.59	2.60	-0.27
3L	1521.0	1526.0	1523.5	3970.0	2.60	2.60	0.22
4U	1508.0	1488.0	1498.0	3027.0	2.02	2.00	1.03
5M	1505.0	1478.0	1491.5	4391.0	2.94	3.00	-1.86
6L	1495.0	1462.0	1478.5	5071.0	3.42	3.50	-2.00
----MEAN APPLIED LOAD = 6330							
1U	1000.0	1011.0	1005.5	2625.0	2.61	2.60	0.40
2M	1003.0	1030.0	1016.5	2623.0	2.58	2.60	-0.75
3L	1014.0	1021.0	1017.5	2655.0	2.60	2.60	0.35
4U	1008.0	986.0*	997.0	2029.0	2.03	2.00	1.75
5M	1007.0	980.0	993.5	2930.0	2.94	3.00	-1.69
6L	989.0	974.0	981.5	3384.0	3.44	3.50	-1.49
----MIN APPLIED LOAD = 3190							
1U	530.0	511.0	520.5	1331.0	2.55	2.60	-1.64
2M	506.0	507.0	506.5	1336.0	2.63	2.60	1.45
3L	511.0	509.0	510.0	1353.0	2.65	2.60	2.03
4U	506.0	496.0	501.0	1033.0	2.06	2.00	3.09
5M	498.0	493.0	495.5	1481.0	2.98	3.00	-0.37
6L	496.0	485.0	490.5	1700.0	3.46	3.50	-0.97

* INDICATES FATIGUE SENSOR STRAIN USED TO CALCULATE MULTIPLIER FACTOR INSTEAD OF STRAIN GAGE

B. MEASURED APPLIED STRAIN CYCLES

GAGE LOC.	SPECIMEN ALT.STRAIN	SPECIMEN MEAN STRAIN	STRAIN GAGE ALT.STRAIN	FATG.SENSOR ALT.STRAIN
1U	495.5	1016.0	1340.5	1604.5
2M	503.2	1009.7	1293.5	1362.5
3L	506.7	1016.7	1308.5	10714.0 △
4U	498.5	999.5	997.0	1045.0
5M	498.0	993.5	1455.0	1803.5
6L	494.0	984.5	1685.5	-16370.5 ▲

C. MULTIPLIER STABILITY DURING STATIC LOAD CYCLE

1)STABILITY CALCULATIONS ARE BASED ON COMPOSITE SENSOR VALUES IN OHMS

2)LOAD EFFECT RATIO = DELTA R UNDER LOAD DIVIDED BY DELTA R AT INITIAL ZERO

SEN NO.	INITIAL ZERO LD	MAX LOAD 9470 LBS	MEAN LOAD 6330 LBS	MIN LOAD 3190 LBS	ZERO LOAD 0 LBS
	COMP. READ.	OHMS VARIATION FROM INITIAL ZERO LOAD COMPOSITE READING			
1U	2.045	0.141	0.101	0.011	0.005
2M	2.541	0.035	0.022	0.008	0.003
3L	2.204	0.081	-2.204 △	-2.204 △	0.059
4U	0.262	0.023	0.012	0.000	-0.001
5M	2.352	0.156	0.139	-0.006	-0.010
6L	5.397	4.098 ▲	3.197	0.091	-0.019
	DELTA R*	LOAD EFFECT RATIO			
1U	2.585	1.056	1.116	1.004	1.001
2M	2.845	1.012	1.009	1.003	1.001
3L	2.815	1.029	0.217 △	0.217 △	1.021
4U	0.552	1.043	1.021	1.001	0.996
5M	3.349	1.046	1.041	0.998	0.997
6L	5.722	1.716	1.558	1.015	0.996

* DELTA R NOT CORRECTED FOR VARIATIONS IN AMBIENT TEMPERATURE

NOTES

▲ See Note 3

△ Fatigue sensor element is open for portions of load cycle

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